CHAPTER 3

REGIONAL WATER RESOURCES

Historically, the Imperial Valley has been dependent on the Colorado River for water. This chapter describes this important resource and discusses other potential sources as well. In particular, groundwater is examined as a possible viable alternative to Colorado River water. The discussion that follows clearly establishes the quantity, quality, and accessibility of all regional water resources to determine IID's optimum water conservation policies later in the study.

3.1 COLORADO RIVER

The Colorado River begins in the northwest portion of Colorado's Rocky Mountain National Park, 70 miles northwest of Denver, and the river meanders southwest for 640 miles through the Upper Basin to Lee Ferry. The Green River, the major tributary of the Colorado River, rises in western Wyoming and discharges into the river in southeastern Utah, 730 river miles south of its origin and 220 miles above Lee Ferry. The Gunnison and San Juan Rivers are the other principal tributaries of the Colorado River in the Upper Basin.

The Colorado River Basin has a total area of approximately 244,000 mi^2 carrying an average annual natural flow of 13 to 15 million AF at Lee Ferry. Of this flow, more than 5 million AF/year are exported to the Arkansas and Missouri River Basins, the Great Basin, Southern California, and the Rio Grande Basin. The Colorado River Basin is a semiarid area. Compared to others such as the Columbia Basin, which drains approximately the same area, it carries a smaller flow (Table 3-1). The northern portion of the basin is characterized by short, warm summers and long, cold winters; many mountain areas are blanketed by deep snow all winter. Much of the intermountain area consists of high basins or valleys with cold winters and hot dry summers. The southern desert portion of the basin has long, hot summers, practically continuous sunshine, and almost a complete absence of freezing temperatures. Rainfall averages 2.5 in./year in the southern end of the basin, while total annual precipitation in the mountains reaches 40 to 60 in.

3.1.1 HYDROLOGY

A. Natural Flow

The Colorado River's long-term average annual flow, as it would have been if undepleted by man, has been estimated to be between 13 and 15 million AF/year. These estimates of natural flow reflect different ways of analyzing the historical flows. If an analysis is made of the flows beginning in 1922, the year after a gauge was established at Lee Ferry, the natural flow is computed to be about 14.3 million AF/year.

Table 3-1 - Comparison of River Basin Drainage

River Basin	Area (1,000 mi^2)	Runoff (million AF/year)	Runoff/ Unit Area (in./year)
Colorado	244	15	1.15
Mississippi	1,234	440	6.70
Columbia	258	180	13.10
Delaware	12	14	20.90

Source: Parsons, 1985.

This estimate agrees well with long-term flow estimates developed through correlations of tree-ring-growth records and Colorado River flows. Using correlations developed through a 70-year historical period, researchers at the University of Arizona's Tree Ring Research Laboratory have reconstructed the runoff of the Colorado River at Lee Ferry going back 450 years. The 450 years of reconstructed runoff lead the researchers to conclude that the long-term virgin flow of the Colorado River is between 13 and 14 million AF/year, with any value in that range being of equal validity. In analyzing all of the available data, the Colorado River Board of California has concluded that the dependable yield of the Colorado River, as measured at Lee Ferry, is about 14 million AF/year.

Table 3-2 shows the natural flow of the Colorado River computed by the USBR for the water years 1906 through 1984. Within a span of only 8 years, computed natural flows have varied from slightly over 5 million AF in 1977 to a provisional estimate of nearly 24 million AF in 1984.

B. Reservoir Storage

Wet and dry cycles have played a significant role in bringing about the development of the Colorado River Reservoir complex. With an annual natural flow variation of from slightly more than 5 million AF to nearly 24 million AF/year, the reservoir system allows capture of sufficient water to maintain the flows of the river to meet downstream needs during dry periods.

The Colorado River and its major tributaries have one of the highest ratios of storage to annual flow of any major river system in the world. The 10 major storage reservoirs in the Colorado River Basin have a total combined conservation and flood control storage capacity of 61,563,000 AF, with 5,350,000 AF reserved for flood control storage on January 1 of each year. This leaves 56,213,000 AF of usable storage capacity available on January 1.

Table 3-2 - Annual Natural Flow of the Colorado River at Lee Ferry
(water years 1906 through 1984)

Water Year	Flow (1,000 AF)	Water Year	Flow (1,000 AF)
1906	18,103	1946	11,086
1907	21,469	1947	15,939
1908	12,307	1948	15,899
1909	22,023	1949	16,682
1910	14,862	1950	13,331
1911	15,008	1951	12,500
1912	19,098	1952	20,919
1913	14,496	1953	11,222
1914	21,086	1954	8,384
1915	14,156	1955	9,813
1916	19,208	1956	11,515
1917	23,864	1957	20,177
1918	15,762	1958	16,939
1919	12,970	1959	9,247
1920	21,948	1960	11,986
1921	22,722	1961	9,279
1922	18,686	1962	17,784
1923	18,362	1963	9,279
1924	14,657	1964	10,814
1925	13,441	1965	18,881
1926	16,146	1966	11,638
1927	18,598	1967	11,834
1928	17,594	1968	13,533
1929	21,442	1969	14,877
1930	15,303	1970	15,360
1931	8,643	1971	15,225
1932	17,584	1972	12,321
1933	12,147	1973	19,435
1934	6,647	1974	13,307
1935	12,297	1975	16,150
1936	14,520	1976	10,723
1937	14,189	1977	5,023
1938	17,946	1978	14,660
1939	11,752	1979	17,337
1940	9,406	1980	16,935
1941	18,347	1981	7,433
1942	19,448	1982	16,126
1943	13,643	1983	23,140
1944	15,532	1984	23,950[a]
1945	13,929		

[a]Provisional.
Source: USBR, 1985.

The construction and filling of the main stem reservoirs of the Colorado River Basin have brought about significant changes in the flow patterns of the river. In addition to the major reservoirs, numerous smaller reservoirs have been built on many of the tributaries. Major storage began with Lake Mead in 1935 and concluded with the filling of Lake Powell in 1980. Reservoirs have a combined storage capacity equal to approximately four times the total average annual natural flow of the Colorado River.

The flows of the San Juan River are controlled by the Navajo Dam, the Green River by Fontenelle and Flaming Gorge Dams, and the Gunnison River by the Wayne N. Aspinall Unit Dams. Glen Canyon Dam is the only major dam on the main stem of the Colorado River above Lee Ferry, but it permits control of almost all flows leaving the Upper Basin.

Lake Mead, formed by Hoover Dam, provides most of the storage and regulation in the Lower Colorado River Basin. Lake Mohave, formed by Davis Dam, backs water at high stages about 67 miles upstream to the tailrace of Hoover Powerplant. Storage in Lake Mohave is used for some reregulation of releases from Hoover Dam, for meeting treaty requirements with Mexico, and for developing power head at Davis Powerplant. The river flows through a natural channel for about 10 miles below Davis Dam, where it enters the Mohave Valley 33 miles above the upper end of Lake Havasu.

Lake Havasu backs up behind Parker Dam for about 45 miles and serves as a forebay from which the MWD of Southern California pumps water into the Colorado River Aqueduct. Lake Havasu also serves as a forebay for the Central Arizona Project pumping plants and aqueducts. Lake Havasu and the Alamo Dam/Reservoir, on the Bill Williams River, are used to control floods originating below Davis Dam and above Parker Dam.

Headgate Rock Dam, Palo Verde Diversion Dam, and Imperial Dam serve as diversion structures with practically no storage. Imperial Dam, located 150 miles downstream from Parker Dam, is the major diversion structure to irrigation projects in the Imperial Valley and Yuma areas.

The Senator Wash Dam, an offstream storage facility, affords regulation in the vicinity of Imperial Dam, assists in the delivery of water to Mexico, and is used for pumpback storage, power generation, and recreation.

The Morelos Dam, located just below the northern International Boundary with Mexico, is the last dam on the Colorado River. This small diversion dam diverts water into the Alamo Canal, which delivers water to northern Mexico.

C. Colorado River Development

Present river depletions above Lee Ferry, Upper Basin, are about 4 million AF and are composed of in-basin uses by agriculture, urban centers, energy development and reservoir evaporation, and of transmountain diversions. Several water development projects are currently under construction in the Upper Basin. When completed and fully operational, these projects will increase depletions in the Upper Basin by several hundred thousand acre-feet per year. In addition, there are plans by Colorado entities to increase the amount of transbasin diversions in their state in the near future. The future rate of growth of energy development industries will also significantly affect river depletions in the Upper Basin.

Irrigation development in the Upper Basin took place gradually from the beginning of settlement in about 1860 but was hastened by the purchase of land from the Indians in 1873. About 800,000 acres were being irrigated by 1905. Between 1905 and 1920, the development of irrigated land increased at a rapid rate, and by 1920, nearly 1.4 million acres were being irrigated. The development then leveled off, and increase since that time has been slow because of physical and economic limitations on the availability of water.

Based on water projects under construction and anticipated future developments, the Colorado River Board anticipates that the Upper Basin's total depletions of Colorado River water will rise to a total of 4.2 million AF by the year 1990, to about 4.8 million AF by the year 2000, and to a less certain 5.8 million AF by the year 2020. This is the full amount of Colorado River water that would be available to the Upper Basin under the Lower Basin's interpretation of the U.S.-Mexico Water Treaty delivery obligations.

In the Lower Basin, irrigation development began at about the same time as in the Upper Basin but was slow because of the difficulty of diverting from the Colorado River with its widely fluctuating flows. Development of the Gila area began in 1875, and the Palo Verde area began in 1879. The agricultural development of the Imperial Valley was begun at the turn of the twentieth century by private entities using Colorado River water. The organization of the District in 1911 consolidated an already extensive irrigation system under a single public agency charged with operations, maintenance, and administration of the system, then serving about 220,000 acres. Since that time, the District has expanded to serve approximately 500,000 acres, while simultaneously upgrading system facilities to improve operating efficiency. Construction of the Boulder Canyon Project in the 1930s and other downstream projects since that time has provided for a continued expansion of the irrigated area. In 1974, nearly 849,000 acres were irrigated from Colorado River diversions below Hoover Dam.

California reached a peak use of Colorado River water in 1974 of 5.3 million AF. Use in 1984 was 4.7 million AF/year, with agricultural use being significantly below the long-term level of use.

Arizona's use of Colorado River water has been fairly constant over the last 10 years and is currently at about 1.2 million AF/year. Although some features of the Central Arizona Project are not scheduled for completion until about 1990, use of project water has been forecast to result in Arizona using its full apportionment of 2.8 million AF/year by about 1988 or 1989. Nevada's current level of use, about 0.1 million AF/year, is expected to grow gradually up to its full apportionment level of 0.3 million AF/year some time after the year 2000.

The delivery obligations to Mexico pursuant to the Mexican Water Treaty are presently being substantially exceeded by the occurrence of surplus water in the river system. During nonsurplus years, and with the Yuma Desalting Plant (expected to be completed about 1990), the deliveries to Mexico will be close to the treaty obligation of 1.5 million AF/year.

D. Historical Flows

The historical flows in the Colorado River are shown for Lee Ferry, the division point between the Upper and Lower Basins (Table 3-3), as well as for three locations below Hoover Dam (Tables 3-4, 3-5, and 3-6), along with corresponding water quality data. The recorded flow at Lee Ferry shown in Table 3-3 is less than the corresponding natural flow because of Upper Basin depletion and storage effects. There are substantial variations from year to year. Historic flows below Hoover largely represent controlled releases from Lake Mead, the effect of increasing river storage and larger upstream diversions. The effect of the current series of wet years, including full conservation storage and substantial flood releases in 1983, is also apparent. These releases have continued through 1984 and are continuing in 1985.

3.1.2 FLOW ALLOCATIONS

For more than 60 years, water rights, laws, and policies have evolved from a series of compacts, Acts of Congress, agreements among Colorado River water users in California, treaties, court opinions and decrees, contracts for water delivery, and other documents relating to the waters of the Colorado River.

A. 1928 Boulder Canyon Project Act

The Supreme Court in Arizona vs. California ruled that Congress in passing the Boulder Canyon Project Act of December 21, 1928 (45 stat. 1057), created its own comprehensive scheme for apportioning the waters of the Lower Colorado River Basin among California, Arizona, and Nevada. The ruling provided that a fair division of the first 7,500,000 AF annually of mainstream water would be 4,400,000 AF to California, 2,800,000 AF to Arizona, and 300,000 AF to Nevada. Further, it left each state its tributaries and provided that Arizona and California should each get one-half of any surplus of mainstream water, over and above the first 7,500,000 AF.

Similarly, in 1929, the California legislature enacted The California Limitation Act (stats. Cal. 1929, ch 16), as called for in Section 4 (a) of the Boulder Canyon Project Act. The Limitation Act provided that California's aggregate annual consumptive use (diversions less returns to the Colorado River) of Colorado River waters apportioned to the Lower Basin States by the Colorado River Compact of November 24, 1922, shall not exceed 4,400,000 AF, plus not more than one-half of any surplus or excess waters unapportioned by the compact.

Section 5 of the Boulder Canyon Project Act provides, in part:

> "No person shall have or be entitled to have the use for any purpose of the water stored as aforesaid except by contract made as herein stated."

Table 3-3 - Colorado River at Lee Ferry: Historic Flow and Quality of Water (1941-1983)

Calendar Year	Flow (1,000 AF)	TDS (mg/L)
1941	17,857	514
1942	14,794	462
1943	11,413	524
1944	13,018	467
1945	11,768	538
1946	8,751	689
1947	14,048	498
1948	12,884	486
1949	14,605	497
1950	10,800	548
1951	9,901	578
1952	17,904	464
1953	8,729	628
1954	6,165	753
1955	6,967	679
1956	8,658	546
1957	18,702	493
1958	13,140	517
1959	7,060	692
1960	8,790	586
1961	7,315	723
1962	14,439	554
1963	1,384	908
1964	3,243	799
1965	11,586	552
1966	7,739	507
1967	7,560	611
1968	8,804	646
1969	9,078	612
1970	8,139	604
1971	9,259	557
1972	9,345	548
1973	9,044	566
1974	8,888	526
1975	8,961	532
1976	9,400	537
1977	7,353	562
1978	9,006	595
1979	8,109	570
1980	11,329	523
1981	7,848	529
1982	9,017	544
1983	19,207	504
Total	442,007	-
Average	10,279	551

Source: USBR, 1985c.

Table 3-4 - Colorado River below Hoover Dam: Historic Flow and Quality of Water (1941-1983)

Calendar Year	Flow (1,000 AF)	TDS (mg/L)
1941	14,886	736
1942	15,762	710
1943	12,715	663
1944	14,427	684
1945	12,512	663
1946	10,585	657
1947	10,959	659
1948	13,050	639
1949	13,567	606
1950	12,016	617
1951	9,870	650
1952	15,816	622
1953	11,300	653
1954	10,514	696
1955	8,588	802
1956	7,813	833
1957	9,323	755
1958	11,878	613
1959	9,282	615
1960	8,996	659
1961	8,586	687
1962	8,615	718
1963	8,533	673
1964	8,159	709
1965	7,792	783
1966	7,781	735
1967	7,932	674
1968	7,838	706
1969	7,892	738
1970	8,023	743
1971	8,164	748
1972	8,099	724
1973	8,301	675
1974	8,732	681
1975	8,367	680
1976	7,927	674
1977	7,873	665
1978	7,476	678
1979	7,721	688
1980	11,088	691
1981	8,284	681
1982	7,454	679
1983	19,067	665
Total	433,566	-
Average	10,083	684

Source: USBR, 1985c.

Table 3-5 - Colorado River below Parker Dam: Historic Flow and Quality of Water (1941-1983)

Calendar Year	Flow (1,000 AF)	TDS (mg/L)
1941	14,748	772
1942	15,196	730
1943	12,079	678
1944	13,842	687
1945	12,033	678
1946	10,141	682
1947	10,662	688
1948	12,650	664
1949	13,060	619
1950	10,473	633
1951	8,672	660
1952	15,413	629
1953	10,649	633
1954	9,671	669
1955	8,141	763
1956	6,869	824
1957	7,997	781
1958	10,890	651
1959	8,186	622
1960	7,794	644
1961	6,975	682
1962	7,159	714
1963	7,251	696
1964	6,653	694
1965	6,356	781
1966	6,680	766
1967	6,322	702
1968	6,642	708
1969	6,438	742
1970	6,658	760
1971	6,911	758
1972	6,788	734
1973	6,847	709
1974	7,171	702
1975	7,210	702
1976	6,697	690
1977	6,711	687
1978	6,685	688
1979	7,195	701
1980	10,723	712
1981	7,229	716
1982	6,367	717
1983	18,625	698
Total	391,458	-
Average	9,104	696

Source: USBR, 1985c.

Table 3-6 - Colorado River at Imperial Dam: Historic Flow and Quality of Water (1941-1983)

Calendar Year	Flow (1,000 AF)	TDS (mg/L)
1941	13,056	668
1942	14,449	665
1943	11,243	690
1944	13,094	694
1945	11,013	700
1946	9,355	694
1947	9,920	710
1948	11,957	688
1949	12,527	639
1950	9,864	656
1951	8,007	686
1952	14,749	647
1953	9,946	669
1954	8,943	707
1955	7,709	807
1956	6,269	891
1957	7,439	848
1958	10,493	726
1959	7,695	730
1960	7,109	769
1961	6,293	802
1962	6,457	820
1963	6,532	800
1964	5,903	822
1965	5,723	888
1966	5,854	886
1967	5,616	841
1968	5,738	838
1969	5,616	877
1970	5,703	896
1971	5,823	892
1972	5,793	861
1973	5,864	843
1974	6,206	834
1975	6,154	829
1976	5,897	822
1977	5,706	819
1978	5,702	812
1979	6,132	802
1980	9,439	760
1981	6,269	821
1982	5,406	826
1983	16,930	710
Total	355,594	-
Average	8,270	752

Source: USBR, 1985c.

B. 1931 Seven-Party Water Agreement

About the time that California was passing its Limitation Act, the City of Los Angeles made water right filings (numbers 4056 and 4760) with the state for waters from the Colorado River. The IID immediately filed a protest and claimed water for 950,000 acres at 4.4 AF/acre annually for a total of 4,180,000 AF. After lengthy negotiations, agreement in principle was reached in February 1930 between agricultural and municipal interests that agriculture should have a priority for the first 3,850,000 AF annually.

After further negotiations among various entities in California, the Seven-Party Water Agreement was executed, dated August 18, 1931. Briefly, it provides the following priorities:

Section 1: A first priority to Palo Verde Irrigation District for 104,500 acres.

Section 2: A second priority to Yuma Project, Reservation Division, for a gross area not to exceed 25,000 acres.

Section 3: A third priority (a) to the IID and other lands to be served from the All-American Canal in Imperial and Coachella Valleys, and (b) Palo Verde Irrigation District for 16,000 acres on Lower Palo Verde mesa, with the total beneficial consumptive use of the first three priorities not to exceed 3,850,000 AF/year of water.

Section 4: A fourth priority to the MWD of Southern California, the City of Los Angeles, and/or others on the Coastal Plain of Southern California, 550,000 AF/year of water.

Section 5: A fifth priority to (a) MWD, City of Los Angeles, and/or others on the Coastal Plain, 550,000 AF/year, (b) City and/or County of San Diego, 112,000 AF/year of water. Priorities in (a) and (b) are equal.

Section 6: A sixth priority to (a) IID and other lands to be served from All-American Canal in Imperial and Coachella Valleys, and (b) Palo Verde Irrigation District for 16,000 acres on adjoining mesa.

Section 7: A seventh priority of all remaining water available for use in California, for agricultural use in the Colorado River Basin in California.

C. 1932 IID Contract for Delivery of Water

In accordance with Section 5 of the Boulder Canyon Project Act, the United States and the IID entered into a "Contract for Construction of Diversion Dam, Main Canal and Appurtenant Structures and for Delivery of Water," on December 1, 1932. Article 17 of the contract provides that the United States shall deliver to the District:

"... so much water as may be necessary to supply the District a total quantity, including all other water diverted for use within the District from the Colorado River, in the amounts and with the priorities in accordance with the recommendations of the Chief of the Division of Water Resources of the State of California, as follows: (Subject to availability thereof for use in California under the Colorado River Compact and the Boulder Canyon Project Act)"

Article 17 then goes on to list the priorities and conditions of the Seven-Party Agreement and further provides that:

"... said water shall be delivered as ordered by the District, and as reasonably required for potable and irrigation purposes within the boundaries of the District in the Imperial and Coachella Valleys in California."

D. 1934 Agreement of Compromise

By contract of February 14, 1934, the IID and Coachella Valley County Water District entered into an agreement that provides that the IID has a prior right to waters apportioned under Priorities 3 and 6 of the Seven-Party Water Agreement of 1931. However, IID's priority over Coachella is conditioned by Article 15 of the Agreement, which states in part:

"Imperial Irrigation District shall have the prior right for irrigation and potable purposes only, and exclusively for use in the Imperial Service Area, as hereinafter defined or hereunder modified..."

E. 1963 Supreme Court Opinion

In the Supreme Court case of Arizona vs. California, the United States claimed that it was entitled to use, without charge against its consumption, waters that the FWS could salvage by elimination of phreatophytes on its wildlife preserves. The Court in its Opinion of June 3, 1963, rejected the United States claim by stating:

"Whatever the intrinsic merits of this claim, it is inconsistent with the Act's command that consumptive use shall be measured by diversions less returns to the river."

F. 1964 Supreme Court Decree

The March 9, 1964, Decree in Arizona vs. California describes "consumptive use" as:

"... diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation."

Because most of IID's return flows do not get back to the Colorado River, essentially all of its diversions flowing beyond the Pilot Knob check structure are charged as consumptive use against its third priority right. The

USBR has been recording and giving credit for return flows that reach the mainstream as surface flows and has been studying, in cooperation with the USGS in Arizona, California, and Nevada, how to identify and measure subsurface return flows that reach the mainstream. The ongoing studies indicate that the total subsurface return flow from the three states to the river is on the order of 100,000 AF/year.

Currently, the USBR is studying how much to credit Imperial and Coachella for seepage from the All-American Canal that returns to the Colorado River from above Pilot Knob.

Article II (B) (1) of the 1964 decree enjoins the United States from releasing water controlled by the United States for irrigation and domestic use in the States of Arizona, California, and Nevada, except as follows:

> "(1) If sufficient mainstream water is available for release, as determined by the Secretary of the Interior, to satisfy 7,500,000 acre-feet of annual consumptive use in the aforesaid three states, then of such 7,500,000 acre-feet of consumptive use, there shall be apportioned 2,800,000 acre-feet for use in Arizona, 4,400,000 acre-feet for use in California, and 300,000 acre-feet for use in Nevada;"

Other subarticles provide for apportionment of waters in excess of 7,500,000 AF/year. If insufficient mainstream water is available for release to satisfy annual consumptive use of 7,500,000 AF in the three states, then the "present perfected rights" are satisfied in the order of their priority dates without regard to state lines.

As relating to the IID, the decree defines present perfected rights as water rights existing as of June 25, 1929, acquired in accordance with state law, which right has been exercised by the actual diversion of a specific quantity of water that has been applied to a defined area of land.

Article VI of the 1964 decree provides:

> "VI. Within two years from the date of this decree, the States of Arizona, California, and Nevada shall furnish to this Court and to the Secretary of the Interior a list of the present perfected rights, with their claimed priority dates, in waters of the mainstream within each state, respectively, in terms of consumptive use, except those relating to federal establishments. Any named party of this proceeding may present its claim of present perfected rights or its opposition to the claims of others. The Secretary of the Interior shall supply similar information, within a similar period of time, with respect to the claims of the United States to present perfected rights within each state. If the parties and the Secretary of the Interior are unable at that time to agree on the present perfected rights to the use of mainstream water in each state, and their priority dates, any party may apply to the Court for the determination of such rights by the Court."

G. 1979 Supreme Court Supplemental Decree

After lengthy negotiations on present perfected rights, various time extensions by the Supreme Court, and many filings of claims and counterclaims, on January 9, 1979, the Court entered a supplemental decree listing the present perfected rights by states and their priority dates. The Court also noted that the quantities fixed for the five Indian reservations by the 1964 decree would remain subject to appropriate adjustment in the event that the boundaries of the reservations are finally determined. The decree further provided priority for the satisfaction in full of the Indian water rights of the 1964 decree in the event of water shortage.

With regard to the IID, the Court decreed present perfected rights as follows:

> "... in annual quantities not to exceed (i) 2,600,000 acre-feet of diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 424,145 acres and for the satisfaction of related uses, whichever of (i) or (ii) is less, with a priority date of 1901."

It must be noted that the present perfected rights are for 35,000 to 40,000 acres less than presently irrigated.

The 1979 supplemental decree also provides that, in the event of a determination of insufficient mainstream water to satisfy present perfected rights, the Secretary of the Interior shall provide priority in satisfying the Indian Reservations as compared to all other present perfected rights, except certain "miscellaneous Present Perfected Rights" listed in the 1979 decree. On this basis, the Court decreed certain present perfected water rights in California, senior to IID, as listed in Table 3-7. The rights listed in Table 3-7, which are senior to any of the rights in the first three priorities in the 1931 Seven-Party Agreement, represent over 50,000 AF/year of consumptive use.

H. 1983 Supreme Court Opinion

As a part of the proceedings and negotiations leading to the 1979 supplemental decree, the five Indian tribes along the lower Colorado River filed motions with the Supreme Court claiming additional water rights for "omitted" lands for which water rights could have been sought in the litigation preceding the 1964 decree and for lands included within various reservations by decisions of the Secretary of the Interior regarding disputed reservation boundaries. The United States also filed a motion with the Court in 1978 claiming additional water rights for the tribes. The Court's Supplemental Decree of January 9, 1979, ordered that Judge Elbert P. Tuttle be appointed Special Master to consider these claims.

After lengthy hearings before the Special Master and arguments before the Supreme Court on December 8, 1982, the Court rendered an opinion on March 30, 1983, and a per curiam and Supplemental Decree on April 16, 1984. With regard to the Indians' claims of additional water rights for "omitted" lands, the Court ruled:

Table 3-7 - Present Perfected Water Rights in California, Senior in Priority to the IID's (under 1964 decree and 1979 supplemental decree)

Defined Area	Present Perfected Rights (AF)	Net Acres	Priority Dates
Chemehuevi Indian Reservation	11,340	1,900	Feb 2, 1907
Yuma Indian Reservation	51,616	7,743	Jan 9, 1884
Colorado River Indian Reservation	10,745	1,612	Nov 22, 1873
	40,241	6,037	Nov 16, 1874
	3,760	564	May 15, 1876
Fort Mohave Indian Reservation	13,698	2,119	Sep 18, 1890
Palo Verde Irrigation District	219,780	33,604	1877
Miscellaneous	3,720	-	1856-1896
Total	354,900	53,579	

Source: B-E, 1983b.

> "In our opinion, the prior determination of Indian water rights in the 1964 Decree precludes relitigation of the irrigable acreage issue."

Indian claims for additional water rights for lands relating to reservation boundary changes were in two categories:

(1) Boundary extensions resulting from secretarial orders since the 1964 decree.

(2) Boundaries determined by judicial decree.

The Court ruled:

> "We cannot agree with the Special Master that the Reservation boundaries extended by secretarial order have been 'finally determined' within the meaning of Article II (D)(5) of our 1964 Decree. With respect to these boundary lines, we ... decline to increase the tribes' water rights at this time. However, with respect to the boundaries determined by judicial decree we ... adopt the Master's conclusions."

The result is that the water rights for the Cocopah Indian Reservation and the Fort Mohave Indian Reservation, both in Arizona, were enlarged from those decrees given in March 9, 1964, and January 9, 1979.

The issue of the secretarial orders extending reservation boundaries is before the U.S. District Court for the Southern District of California in the case Metropolitan Water District vs. United States, Civ. No. 81-0678 - GT(M) (April 28, 1982). A court decision adverse to the MWD and based on the claims of the United States and the Indian tribes could result in the tribes gaining the following additional water rights:

Indian Reservation	AF
Fort Mohave	14,600
Colorado River	22,810
Fort Yuma	77,410

The first two of these would be senior to the first three priorities of the Seven-Party Agreement, and the last would be a part of the second priority.

I. Summary of Water Rights with Priority Senior to IID

As indicated heretofore, the Palo Verde Irrigation District and the Reservation Division of the Yuma Project, as listed in the 1931 Seven-Party Agreement, hold water rights senior to the IID. In addition, the Supreme Court Decrees of 1964 and 1979 list present perfected rights (Table 3-7) that are senior to IID's water rights. The estimated annual consumptive uses required to satisfy senior present perfected rights and contractual rights are listed in Table 3-8.

Table 3-8 - Estimated Annual Consumptive Use under Colorado River Water Rights in California, Superior to IID's

Area	Estimated Annual Consumptive Use (AF) (rounded) (diversions minus returns)
Palo Verde Irrigation District	450,000
Reservation Division - Yuma Project	60,000
Colorado River Indian Reservation	35,000
Fort Mohave Indian Reservation	9,000
Chemehuevi Indian Reservation	8,000
Miscellaneous	4,000
Total	566,000

Source: Parsons, 1985.

From Tables 3-7 and 3-8, it can be seen that the expected consumptive use by already decreed present perfected rights and contractual rights in California totals approximately 3,166,000 AF, which is well below the 3,850,000-AF limitation of the first three priorities of the Seven-Party Agreement. Therefore, the agreement becomes the controlling limitation on IID.

California's 4.4 million AF/year under the 1964 decree appears to be assured, even in low flow cycles of the Colorado River, inasmuch as the Colorado River Basin Project Act of September 30, 1968 (82 Stat. 885), which authorized the Central Arizona Project, provided that in any year in which there is insufficient main stream Colorado River water to satisfy annual consumptive use of 7.5 million AF in Arizona, California, and Nevada, the 1964 decree shall be so administered as to ensure the availability of California's 4.4 million AF. In other words, the delivery of California's 4.4 million AF/year has a priority over delivery of water to the Central Arizona Project.

J. Consumptive Use Within First Three Priorities

Table 3-9 lists consumptive uses for the years 1980 to 1984 by those holding the first three priorities under the Seven-Party Agreement. Some reductions in consumptive use since 1982 may be attributable to water conservation measures; however, there are strong indications that the reductions are more closely related to the U.S. Department of Agriculture's set-aside programs and cutbacks in cropping during poor economic times on farms.

The Central Arizona Project is expected to become operational by the end of 1985. Although the Secretary of the Interior has not yet issued operating criteria for long-range operation of the Lower Colorado River Basin reservoirs, it is anticipated that shortly after the Central Arizona Project starts diverting, the Secretary will notify the states that their annual consumptive uses are to be limited to those in Article II (B)(1) of the 1964 decree, i.e., California 4.4 million AF/year.

MWD, with a fourth priority for 550,000 AF/year but currently receiving much more, will be the first affected by such a 4.4-million-AF limitation. It is assumed that MWD would insist that those holding the first three priorities restrict their combined consumptive use to 3,850,000 AF/year and that those with present perfected rights outside of and senior to the areas served by the first three priorities restrict their consumptive use to no more than their decreed rights of approximately 50,000 AF/year. There is a potential for the 50,000-AF figure to increase to 165,000 AF if the courts support the position of the United States. In the latter instance, MWD's fourth priority would be reduced to 295,000 AF/year if the first three priorities were using their full 3,850,000 AF.

K. Potential for Reducing Consumptive Use by First Three Priorities

The Palo Verde Irrigation District, which holds a first priority for water to irrigate 104,500 acres of valley lands, is essentially a "closed basin" where nearly all diverted water in excess of consumptive use returns to the Colorado River. There appears to be little likelihood of any reduction in irrigated acreage or radical change in cropping pattern that would affect consumptive

Table 3-9 - Consumptive Use of Colorado River Water by Entities Holding Top Three Priorities under the 1931 Seven-Party Agreement

User	Year	Acre-Feet Diversions	Returns	Consumptive Use
Imperial	1980	2,845,779[a]	-	2,845,779
Irrigation	1981	2,595,578[a]	-	2,595,578
District	1982	2,565,475[b]	-	2,565,475
	1983	2,509,289[b]	-	2,509,289
	1984	2,687,114[b]	-	2,687,114
5-year average				2,640,647
Coachella	1980	531,791[a]	-	531,791
Valley	1981	452,260[a]	-	452,260
Water	1982	419,536[b]	-	419,536
District	1983	355,324[b]	-	355,324
	1984	358,546[b]	-	358,546
5-year average				423,491
Palo Verde	1980	906,455	488,151	418,304
Irrigation	1981	1,007,553	483,719	523,835
District	1982	941,974	485,074	456,900
	1983	786,664	453,143	333,521
	1984	802,270	503,321	298,949
5-year average				406,302
Reservation	1980	90,108	28,323	61,785
Division	1981	94,507	34,563	59,944
Yuma	1982	87,816	28,131	59,685
Project	1983	63,152	20,359	42,792
	1984	67,240	26,408	40,832
5-year average				53,008
Total average (last 5 years)				3,523,448
Potential additional consumptive use				
Lower Palo Verde Mesa (additional potential)				55,000
Reservation Division (additional potential)				77,410
Average (including additional potential)				3,655,858

[a]At Imperial Dam.
[b]At Palo Verde Channel.
Source: Parsons, 1985.

use. Therefore, it is unlikely that the Palo Verde Irrigation District will or can significantly reduce consumptive use on its valley lands.

The Reservation Division of the Yuma Project, which holds the second priority for 25,000 acres, is also part of a closed system where essentially all diverted water in excess of consumptive use returns to the Colorado River. As with the Palo Verde Irrigation District, no reduction in acreage irrigated or change in cropping pattern is expected. Therefore, there is little opportunity for a reduction in consumptive use on the presently irrigated acreage. Within the irrigated acreage, the Indian Reservation holds rights senior to the IID's on 7,743 acres under the 1964 decree. As indicated heretofore, if the MWD should lose its court case, the reservation would hold water rights senior to the IID's that would represent an additional consumptive use of 77,412 AF/year over current uses.

Within the third priority, on an equal basis with the lands to be served from the All-American Canal in Imperial and Coachella Valleys, are 16,000 acres on Lower Palo Verde mesa. Only a small part of that acreage is now being irrigated by diversion of Colorado River water. If the full 16,000 acres were to be irrigated with Colorado River water, it would consumptively use an additional 50,000 to 60,000 AF/year as compared to current uses.

L. 1944 Mexican Treaty

The Mexican Treaty of 1944 between the United States and Mexico provides for the delivering of 1,500,000 AF/year of water with further provisions for sharing of surpluses and shortages. Deliveries to Mexico are to be supplied from water surplus to the Upper and Lower Basin apportionments. If the water surplus to these quantities is insufficient, the deficiency is borne equally by the Upper and Lower Basins. Davis Dam was completed in 1950, as required by the Treaty to reregulate the flows released from Hoover Dam.

Minute No. 242 (of August 30, 1973) of the International Boundary Commission provides that the approximately 1,360,000 AF delivered to Mexico upstream of Morales Dam shall have an average salinity of no more than 115 ppm ±30 ppm (U.S. count) over the annual average salinity of Colorado River waters that arrive at Imperial Dam. This provision gave rise to the reverse-osmosis plant now under construction near Yuma to desalt return flows from the Wellton Mohawk Irrigation and Drainage District.

3.1.3 COLORADO RIVER YIELD

As shown previously, the dependable yield of the Colorado River, as measured at Lee Ferry, is about 14 million AF. Table 3-10 shows the disposition of Colorado River supply for the period 1976 to 1980. During this period, water use was well below the estimated long-term dependable yield, although computed natural flows were also below average.

The Colorado River Board of California has estimated river depletions for a range of years using the water-use values discussed previously. These depletions in comparison to estimated dependable yield are shown in Table 3-11.

Table 3-10 - Average Water Use of the Colorado River (1976-1980)

Type of Use	1,000 AF
Reservoir evaporation	2,114
Irrigated agriculture	3,473
Municipal and industrial	271
Fish, wildlife, and recreation	50
Transbasin exports	3,525
Deliveries to Mexico	2,847
Total	12,280

Source: USBR, 1985.

Table 3-11 - Projected Colorado River Depletions (1984-2020)

Depletions	Year (million AF) 1984	1990	2000	2020
Upper Basin	4.0	4.2	4.8	5.8
Mexico deliveries	1.5	1.5	1.5	1.5
River losses, Lower Basin	0.6	0.6	0.6	0.6
California	4.7	4.4	4.4	4.4
Arizona	1.2	2.8	2.8	2.8
Nevada	0.1	0.1	0.2	0.3
Total	12.1	13.6	14.3	15.4
Estimated dependable yield[a]	14.3	14.3	14.3	14.3
Excess of yield over depletions	2.2	0.7	0.0	-1.1

[a]Approximate mean annual natural flow at Lee Ferry (1922-1983).
Source: Colorado River Board of California, 1985; Parsons, 1985.

Since the completion of the Glen Canyon Dam in 1963, a surplus of supply over demand has been going into reservoir storage. From 1963 through 1978, very little water passed the International Boundary that was not needed to meet the requirements of the 1944 Mexican Water Treaty. However, commencing in 1979, the combination of extremely high flows on the Gila River and the nearly full conditions of the Colorado River reservoirs required some excess releases to be made to Mexico.

The period of 1963 to 1980 represents the most significant period of reservoir storage in the history of water development on the Colorado River. Storage in Flaming Gorge Reservoir, Lake Powell, and Lake Mead increased from less than 20 million AF in 1963 to over 50 million AF by 1980. The spill of Glen Canyon Dam in 1980 ended the initial filling of the major reservoirs on the Colorado River. Currently, conservation storage in the Colorado River is full, and releases in excess of downstream needs continue to be made.

With initial deliveries of water to the Central Arizona Project in 1985, California may be limited to its allocation of 4.4 million AF/year, subject to criteria being formulated by the Secretary of the Interior. It is expected that the current Colorado River surplus and full conservation storage, coupled with initial limited depletion by the Central Arizona Project, will provide ample supplies for several years. However, it is projected that water demands may exceed dependable yield some time during the decade of 2000 to 2010. For several years after the time that total use exceeds the dependable yield, water needs can be maintained by drawing down the water in storage in the system's reservoirs, but eventually shortages would have to be taken in accordance with the Law of the River.

To fully consider these factors, a further study was undertaken of the Colorado River annual flow variations. The period of 1922 to 1983 was selected as the base for frequency analysis, using both the California Method and the Pearson Type III Method (Chow, 1968; Viessman et al., 1972). This base period was selected to reduce the distortion of results caused by using data from the abnormally high flow 1906-1921 era. The California Method was first employed in California and has been used extensively by the Colorado River Board of California. The Pearson Type III Method has been widely adopted as the standard method for flow frequency analysis and, in fact, is recommended by the U.S. Water Resources Council. To apply these methods, the events being analyzed (in this case, the Colorado River's annual natural flow at Lee Ferry) are ranked starting with the highest flow (No. 1), second highest flow (No. 2), etc., until all events have been ranked. Different equations relate the rankings to frequency distributions characteristic of the two methods. The methodology is presented in various references should further details be desired. The outcome is shown in Table 3-12 and Figure 3-1. The results indicate a relatively close agreement between the two analytical methods. The findings are related to the IID's water allocation in Table 3-13. Because the Pearson Type III methodology tends to yield slightly more conservative results, i.e., low flow at greater frequency, Table 3-13 reflects the Pearson results. The table clearly indicates that even when a low flow occurs, which will probably not be seen again for a hundred years, the only effect is that a 9.8 million AF/year release from storage will be required. In the highly unlikely event that two such droughts occur in successive years (which might

Table 3-12 - Flow Frequency Analysis
(data base: 1922 to 1983)

Event Ranking	Annual Natural Flow at Lee Ferry (1,000 AF/year)	Frequency (%) California Method	Frequency (%) Pearson Type III Method
1	23,140	1.61	0.65
2	21,442	3.23	3.09
3	20,919	4.81	4.36
4	20,177	6.45	7.18
5	19,448	8.06	9.94
6	19,435	9.68	10.02
7	18,881	11.29	13.30
8	18,686	12.90	14.47
9	18,598	14.52	15.00
10	18,362	16.13	16.41
11	18,347	17.74	16.50
12	17,946	19.35	18.90
13	17,784	20.97	19.87
14	17,594	22.58	21.48
15	17,584	24.19	21.57
16	17,337	25.81	23.73
17	16,939	27.42	27.22
18	16,935	29.03	27.26
19	16,682	30.65	29.47
20	16,150	32.26	34.13
21	16,146	33.87	34.16
22	16,126	35.48	34.34
23	15,939	37.10	35.98
24	15,899	38.71	36.33
25	15,532	40.32	39.55
26	15,360	41.94	41.05
27	15,303	43.55	41.55
28	15,225	45.16	42.24
29	14,877	46.77	45.29
30	14,660	48.39	47,19
31	14,657	50.00	47.22
32	14,520	51.61	48.42
33	14,189	53.23	51.30
34	13,929	54.84	53.55
35	13,643	56.45	56.03
36	13,533	58.06	56.98
37	13,441	59.68	57.78
38	13,331	61.29	58.73
39	13,307	62.90	58.94
40	12,500	64.52	65.94
41	12,321	66.13	67.49
42	12,297	67.74	67.69

Table 3-12 (Contd)

Event Ranking	Annual Natural Flow at Lee Ferry (1,000 AF/year)	Frequency (%) California Method	Frequency (%) Pearson Type III Method
43	12,147	69.35	68.99
44	11,986	70.97	70.39
45	11,834	72.58	71.71
46	11,752	74.19	72.42
47	11,638	75.81	73.41
48	11,515	77.42	74.47
49	11,222	79.03	77.01
50	11,086	80.65	78.19
51	11,086	80.65	78.19
52	10,723	83.87	80.89
53	9,813	85.48	86.17
54	9,406	87.10	88.53
55	9,279	88.71	89.26
56	9,279	90.32	89.26
57	9,247	91.94	89.45
58	8,643	93.55	91.92
59	8,384	95.16	92.90
60	7,433	96.77	95.71
61	6,647	98.39	97.12
62	5,023	100.00	99.38

Source: Parsons, 1985.

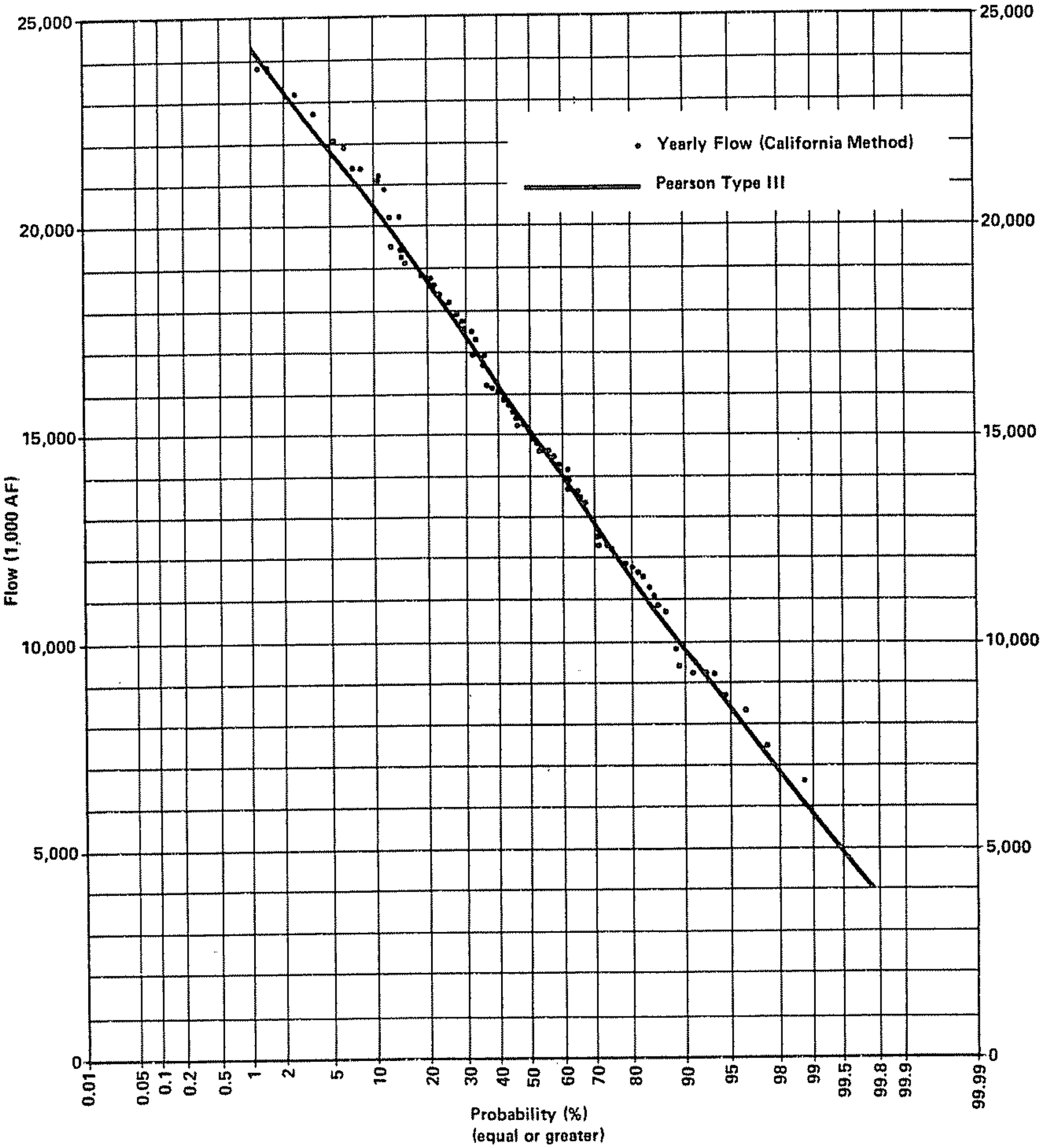


Figure 3-1 - Colorado River Natural Flow Frequency at Lee Ferry
(Parsons, 1985)

Table 3-13 - Effect of Colorado River Low Flow on Water Use

Event[a] Frequency (%)	Event Recurrence[b] Interval (years)	Natural Colorado[c] River Flow (1,000 AF/year)	Release from[c] Storage (1,000 AF/year)	Year 2010 Expected Total Demand (1,000 AF/year)	Year 2010 Flow to California (1,000 AF/year)
50	2	14,300	1,100	15,400	4,400
80	5	10,900	4,500	15,400	4,400
90	10	9,200	6,200	15,400	4,400
99	100	5,600	9,800	15,400	4,400

[a] Probability that natural flow at Lee Ferry will equal or exceed flow shown.
[b] Period when flow is expected to occur once or less.
[c] Values shown rounded to nearest 100 AF.
Source: Parsons, 1985.

occur about once every 10,000 years), there would probably still be very little effect on water deliveries because there is over 50 million AF of water in storage. In other words, it is highly unlikely that any short-term phenomenon such as an annual drought would cause a reduction in water deliveries to those with rights to Colorado River water.

The long-term outlook for the lower basin is not as good because the dependable yield is about 1.1 million AF less than the total expected use in year 2010 (Table 3-13). The lowest priority among lower basin water users is held by Arizona for 1.6 million AF/year of the Central Arizona Project's allocation. Because the 1.6 million AF/year more than offsets the projected 1.1 million AF/year shortfall, it is clear that the other Colorado River water users, including the IID, can plan on a steady supply with no significant limitation. The net effect to the IID is that the 3.85 million AF/year allocated to the California agricultural agencies via the Seven-Party Agreement should be available with greater than 99% certainty. This general position is supported by the Colorado River Board (CRBC, 1985).

3.1.4 WATER QUALITY

Salinity is of major importance and concern in the Colorado River. Salt concentrations are due to natural diffuse and point sources, and the concentrating effect of evaporation, return flows, and diversions. Most of the salinity in the Colorado River derives from sources upstream from California, but there are local contributions in the Palo Verde region.

The historic and present salinity in the river is described below, the Salinity Control Program is discussed, and future salinity is reviewed.

A. Historic Water Quality

The largest contribution to Colorado River salinity is from natural diffuse and point sources. A number of the sedimentary formations in the basin were deposited in marine or brackish water environments and, as water moves through these sediments, the saline water is displaced and leached. Irrigation in the Upper Colorado River Basin has increased in salinity in the Colorado River. Return flows from the irrigated lands dissolve salts from the soils and underlying aquifer material and transport them to the river. The development of future irrigation projects will further increase the salt load to the river.

The addition of salts to the river system is not the only cause of increased salinity concentrations. The depletion of better quality water in the Upper Basin produces a concentrating effect on the waters of the downstream reaches. This concentrating effect occurs to a greater degree when the diverted salts return to the river than when they are depleted along with the water. Because the Lower Basin has already developed most of its water supply with the exception of the Central Arizona Project, most of the additional future depletions will be developed in the Upper Basin.

Evaporation from water surfaces, principally from reservoirs, concentrates the salts in the remaining water. With an estimated reservoir evaporation of over 2 million AF/year, this effect may, under average conditions, increase salinity on the order of 15%. Salt loads contributed to the Colorado River system by municipal and industrial sources are generally minor, totaling about 1% of the basin salt load. Future increases in salt loads from these sources are expected to be small with regard to the total basin salt burden and will have only a minor effect on salinity levels.

Historic salinity in the Colorado River is shown in Tables 3-3 through 3-6. At Imperial Dam, salinity has varied from an annual average of 656 ppm TDS in 1950 to 896 ppm in 1970. The salinity concentration generally decreases with increased flow on an annual basis. Years of lower flows are characterized by higher TDS concentrations than years of higher flows.

One of the most significant changes in the salinity of the Colorado River is due to the regulation of the natural flow of the river basin. Because of the effects of dilution, the natural, annual variation of the river flow caused salinity to vary inversely to flow. This seasonal variation in both flow and salinity has been greatly reduced by the regulation of the basin.

Salinity concentrations at Imperial Dam decreased steadily from 1970 to 1979, dropped notably in 1980, increased sharply in 1981 to 1982, and dropped again in 1983. The 1970 to 1980 salinity concentrations show the buffering of annual fluctuations in salinities due to the effect of nearly 50 million AF of reservoir storage. With the reservoir storage in the Colorado River at near capacity, discharges from Hoover Dam increased from 7.7 million AF in 1979 to 11.1 million AF in 1980, temporarily diluting the salinity at Imperial Dam. With more normal flows in 1981 and 1982, the salinity rebounded. Higher releases from Hoover and Glen Canyon Dams in 1983, combined with lower salinities in water in storage, caused salinity at Imperial Dam to drop again. With the over 50 million AF of high quality water in storage, salinities at Imperial Dam should remain low through 1985.

B. Legislation

Although a number of water quality-related legislative actions have been taken on the state and federal levels, four federal acts are of special significance to the Colorado River Basin:

(1) Water Quality Act of 1965 and related amendments.

(2) Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

(3) Colorado River Basin Salinity Control Act of 1974.

(4) Clean Water Act of 1977.

Also central to water quality issues are agreements with Mexico on Colorado River system waters entering that country.

The Water Quality Act of 1965 (Public Law 89-234) amended the Federal Water Pollution Control Act and established a Federal Water Pollution Control Administration (now the EPA). Among other provisions, it required states to adopt water quality criteria for interstate waters inside their boundaries.

The seven Basin States initially developed water quality standards that did not include numeric salinity criteria for the Colorado River, primarily because of technical constraints. In 1972, the states agreed to a policy that called for the maintenance of salinity concentrations in the Lower Colorado River system at or below existing levels, while the Upper Basin States continued to develop their compact-apportioned waters. The states suggested that the USBR should have primary responsibility for investigating, planning, and implementing the proposed Colorado River Basin Salinity Control Program with the assistance of the Federal Office of Saline Water and the EPA.

The enactment of the Federal Water Pollution Control Act Amendment of 1972 affected salinity control in that the legislation was interpreted by EPA to require numerical standards for salinity in the Colorado River. In response, the Basin States founded the Colorado River Basin Salinity Control Forum to develop numeric salinity criteria and a basinwide plan of implementation for salinity control. The forum recommended that the individual Basin States adopt the following report: Water Quality Standards for Salinity, Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System. The proposed water quality standard called for maintenance of flow-weighted average TDS concentrations of 723 mg/L below Hoover Dam, 747 mg/L below Parker Dam, and 879 mg/L below Imperial Dam. Included in the plan of implementation were four salinity control units and possibly additional units, the application of effluent limitations, the use of saline water whenever practicable, and future studies. The standards are to be reviewed at 3-year intervals. All of the Basin States adopted the 1975 Forum-recommended standards.

The 1974 Colorado River Basin Salinity Control Act (Public Law 93-320) provided the means to comply with U.S. obligations to Mexico that included as a major feature a desalination plant and brine discharge canal. These facilities will enable the United States to deliver water to Mexico having an average salinity no greater than 115 ppm ±30 ppm (U.S. count) over the annual average salinity of Colorado River waters at Imperial Dam. The act also authorized construction of 4 salinity control units and the expedited planning of 12 other salinity control projects above Imperial Dam as part of the basinwide salinity control plan.

In 1984, the Forum reviewed the salinity standards that were adopted by all of the seven Basin States and recommended the construction of 3 of the 4 salinity control units and 10 of the 12 projects identified in the 1974 act, the placing of effluent limitations on industrial and municipal discharges, and the reduction of the salt-loading effects of irrigation return flows. The plan also called for the inclusion of water quality management plans to comply with Section 208 provisions after the adoption of the plans by the states and approval by EPA. It also contemplated the use of saline water for industrial purposes and future salinity use control methods.

The 98th Congress passed H.R. 2790, which amends Public Law 93-320, the Colorado River Basin Salinity Control Act. The President signed the bill on October 30, 1984, and the legislative initiative has become Public Law 98-569. This action is the culmination of a significant 2-1/2-year effort by the Colorado River Basin States working in close cooperation with the involved federal agencies to amend, enhance, and update the 10-year-old Salinity Control Act.

The Colorado River Basin Salinity Control Act, as now amended, provides the authority for the pursuit of salinity control measures, primarily by the Department of the Interior and the Department of Agriculture, that will allow for the necessary salinity controls on the river to be put in place through the year 2000. It will ensure, if implemented, the compliance with the numeric criteria at least through the year 2005.

C. Salinity Control Program

Title I of the Colorado River Basin Salinity Control Act, Public Law 93-320, authorized the Secretary of the Interior to proceed with a program of works of improvement for the enhancement and protection of the quality of water available in the Colorado River for use in the United States and the Republic of Mexico. Title I enables the United States to comply with its obligation under the agreement with Mexico of August 30, 1973 (Minute No. 242 of the International Boundary and Water Commission, United States and Mexico), that was concluded pursuant to the Treaty of February 3, 1944.

Title II of the Colorado River Basin Salinity Control Act authorized the Secretary of the Interior to construct, as part of the Colorado River Salinity Control Program, the Grand Valley Unit, the Las Vegas Wash Unit, the Lower Gunnison Basin Unit, portions of the McElmo Creek Unit, and the Paradox Valley Unit. Another unit, the Meeker Dome Unit, was completed in a verification well plugging program.

Table 3-14 presents the salinity control programs that have been constructed or planned in the Colorado River Basin.

In the Lower Basin, present peak TDS concentrations are approaching critical levels for some salt-sensitive crops. Although the water is suitable for irrigating most crops, TDS concentrations are high enough that special irrigation practices are used in some cases. At the present time, TDS concentrations are being maintained below the standards. Complete development of apportioned water by the states will result in increases in TDS that would be more detrimental to agriculture without salinity control measures.

The USBR published a document entitled, "Colorado River Salinity--Economic Impacts on Agricultural, Municipal, and Industrial Users." The estimated future annual damages to the Lower Basin water users in 1976 dollars were $343,00 for each 1 mg/L increase in TDS at Imperial Dam when concentrations reach the range of 875 mg/L to 1,225 mg/L. The damage figure is approximately $561,000 per mg/L in 1984 dollars. These annual damages were calculated using the 1972 salinity standard of 879 mg/L (approved by EPA in 1975) and a projected full-development salinity concentration of 1,225 mg/L at Imperial Dam.

The annual municipal damages are divided as: MWD, 54%; Central Arizona Project, 8%; and lower main stem users, 8%. Total agriculture annual damages are 30%.

Table 3-14 - Summary of Salinity Control Program

Unit	Potential Salt Reduction[a] (1,000 tpy)	Estimated Salt Reduction to Date (1,000 tpy)	Annual Cost Effectiveness[b] ($/ton)	Effect at Imperial Dam: TDS Reduction (mg/L)	Effect at Imperial Dam: Annual Cost Effectiveness[b] ($000 mg/L)
U.S. Department of the Interior (USDI)					
Authorized for Construction and/or Completed					
Grand Valley, Stage I	28	17.7	72	2.8	719
Grand Valley, Stage II	136	-	77	13.6	766
Las Vegas Wash	92	-	10	9.2	102
Lower Gunnison Basin	141	-	71	14.1	712
McElmo Creek	24	-	50	2.4	500
Meeker Dome	57	48.0	15	4.8	152
Paradox Valley	180	-	25	18.0	250
Authorized for Planning					
Big Sandy River	78	-	69	7.8	691
Dirty Devil River	20	-	74	2.0	740
Glenwood-Dotsero Springs	284	-	121	28.4	1,210
LaVerkin Springs	53	-	190	5.3	1,900
Lower Gunnison Basin, North Fork	-[c]	-	-[c]	-[c]	-[c]
Lower Virgin River	-[c]	-	-[c]	-[c]	-[c]
Palo Verde Irrigation District	11	-	28	1.1	280
Price-San Rafael Rivers	30	-	35	3.0	350
Saline Water Use	160	-	-[c]	-[c]	-[c]
San Juan River	-[c]	-	-[c]	-[c]	-[c]
Sinbad Valley (BLM)	7	-	75	0.7	751
Uinta Basin	26	-	90	2.6	903
U.S. Department of Agriculture (USDA)[d]					
Authorized for Construction					
Big Sandy River	35	-	30	3.5	300
Grand Valley	130	23.3	24	13.0	240
Lower Gunnison Basin	335	-	56	33.5	560
Mancos Valley (preliminary)	20	-	89	2.0	890
McElmo Creek	38	-	79	3.3	790
Moapa Valley	20	-	38	2.0	380
Price River (preliminary)	62	-	-[c]	6.2	-[c]
San Rafael River (preliminary)	62	-	-[c]	6.2	-[c]
Uinta Basin	77	12.8	96	7.6	960
Virgin Valley	37	-	9	3.7	90

[a] Reflects values presently included in USBR Colorado River simulation system data base.
[b] The estimates represent, at best, appraisal-level costs in some cases and feasibility-level costs in other cases. Caution must be used in drawing comparative conclusions in attempting to prioritize projects on the basis of these cost-effectiveness values.
[c] Figures not available.
[d] Indexed to 1982 prices.
Source: USBR, 1985.

D. Future Water Quality

The quality of water available to the IID in the future is a matter of great concern. Because California is located at the lower end of the Colorado River Basin, the water that it diverts contains all of the dissolved salts that have entered the river upstream. And because of its high salinity, Colorado River water requires special management so that crop yields may be maintained and low-salt-tolerant plants will not be damaged or killed. Agricultural areas of California are already suffering significant economic detriments in their utilization of Colorado River water. Those detriments will increase if Colorado River salinity levels are allowed to increase with the development of the Colorado River Basin.

Equally significant, particularly in the future, is the fact that the amount of water required for leaching salts below the root zone increases with higher salinities and the effectiveness of leaching becomes less with higher salinities, particularly with the heavier soils commonly found in the Imperial Valley.

Salinity standards of 879 mg/L have been established at Imperial Dam. Current salinity is substantially below that with current conditions of surplus flows. The USBR has estimated future salinity conditions at Imperial Dam with and without additional salinity control projects. These are shown in Table 3-15. The projected levels of salinity, both with and without further salinity control measures, will create problems for salinity-sensitive crops and will require additional water for leaching over that currently needed.

Table 3-15 - Projected Salinity at Imperial Dam
(average conditions)

Condition	Year (TDS in mg/L)			
	1982	1990	2000	2010
With planned salinity control projects	824	808	850	904
Without further salinity control projects	824	821	937	1,012

Source: USBR, 1985.

3.1.5 LEGAL CONSIDERATIONS

The "Law of the River" has evolved out of the combination of federal and state statutes, interstate compacts, court decrees, U.S. contracts, treaties, operating criteria, and administrative decisions previously mentioned. This law includes recognition of the District's present perfected rights, which are water rights acquired in accordance with state law. Moreover, the District's present perfected rights are fully recognized and protected by virtue of the U.S. Supreme Court decision Arizona vs. California and are not subject to the use limitations contained in the Compact, the Boulder Canyon Project Act, or the Seven-Party Agreement.

State law now provides that conserved water "may be sold, leased, exchanged, or otherwise transferred . . ." and the reduction in use resulting from conservation efforts "shall be deemed equivalent to a reasonable beneficial use of water to the extent of such cessation or reduction in use . . ." (Water Code Section 1011). Water Code Section 109 declares it to be the "established policy of this State to facilitate the voluntary transfer of water and water rights where consistent with the public welfare of the place of export and the place of import." In addition, Water Code Section 1244 provides:

> "The sale, lease, exchange, or transfer of water or water rights, in itself, shall not constitute evidence of waste or unreasonable use, unreasonable method of use, or unreasonable method of diversion and shall not affect any determination of forfeiture applicable to water appropriated pursuant to the Water Commission Act or this Code or water appropriated prior to December 19, 1914."

Water Code Section 22259 authorizes the Imperial Irrigation District's Board to ". . . enter into a contract for the lease or sale of any surplus water or use of surplus water not necessarily for use within the District, for use either within or without the District." With regard to existing contracts, neither the Seven-Party Agreement nor the District's Water Delivery Contract with the Secretary of the Interior reveals any explicit prohibition against the transfer of surplus water.

In summary, the Law of the River and related federal water policies are consistent and in harmony with California law and policy, which:

- o Encourages the Imperial Irrigation District to conserve and thereby maximize the beneficial use of its waters to serve the public interest.
- o Permits the Imperial Irrigation District to transfer its conserved water to other users without jeopardy to its allocation under the Law of the River.
- o Authorizes water, or the right to the use of water, the use of which has been reduced as a result of water conservation effort, to be sold, leased, exchanged, or otherwise transferred.
- o Indicates that the District's rights to transferred water are fully protected by Section 1012 of the California Water Code.

As such, it is believed that it is legally permissible for the Imperial Irrigation District to transfer water (not water rights) to other users outside of the District without the approval of any other priority user or the Secretary of the Interior.

3.2 GROUNDWATER

Groundwater as an alternative to Colorado River water has not been fully exploited in the past because of its questionable water quality. However, findings in the East Mesa area indicate that water of acceptable quality is available; moreover, even relatively saline water may have some use. For these reasons, a thorough review of groundwater conditions is called for.

3.2.1 AQUIFER SYSTEM

The groundwater basin of Imperial Valley is located in the northern portion of the Salton Trough (described in subsection 2.1.2). The geologic formation and its setting have been extensively described by the USGS (1975), as well as various other agencies. The trough is overlaid by thick sediments, including Holocene through Eocene, nonmarine Tertiary, and marine deposits and sedimentary rocks on a basement complex pre-Tertiary plutonic and metamorphic rock from about 10,000 ft on the east to over 20,000 ft in the western portion. The subsurface deposits underlying the area are predominantly nonmarine sediments from the Colorado River. Generally, these river deposits consist of silt, sand, and clay, as contrasted with locally derived deposits of coarse sand and gravel near the margins of the valley. Consequently, these nonmarine sediments and alluvial deposits are unconsolidated and found as a groundwater reservoir.

The groundwater reservoir considered as the aquifer in the Imperial Valley area is principally the upper few thousand feet of the heterogeneous sequence of nonmarine deposits. At depths greater than a few thousand feet, the groundwater is usually too saline for irrigation and most other uses, and the hydraulic connection is poor between the water in the deeper deposits and the water in the upper part of the groundwater reservoir (USGS, 1975).

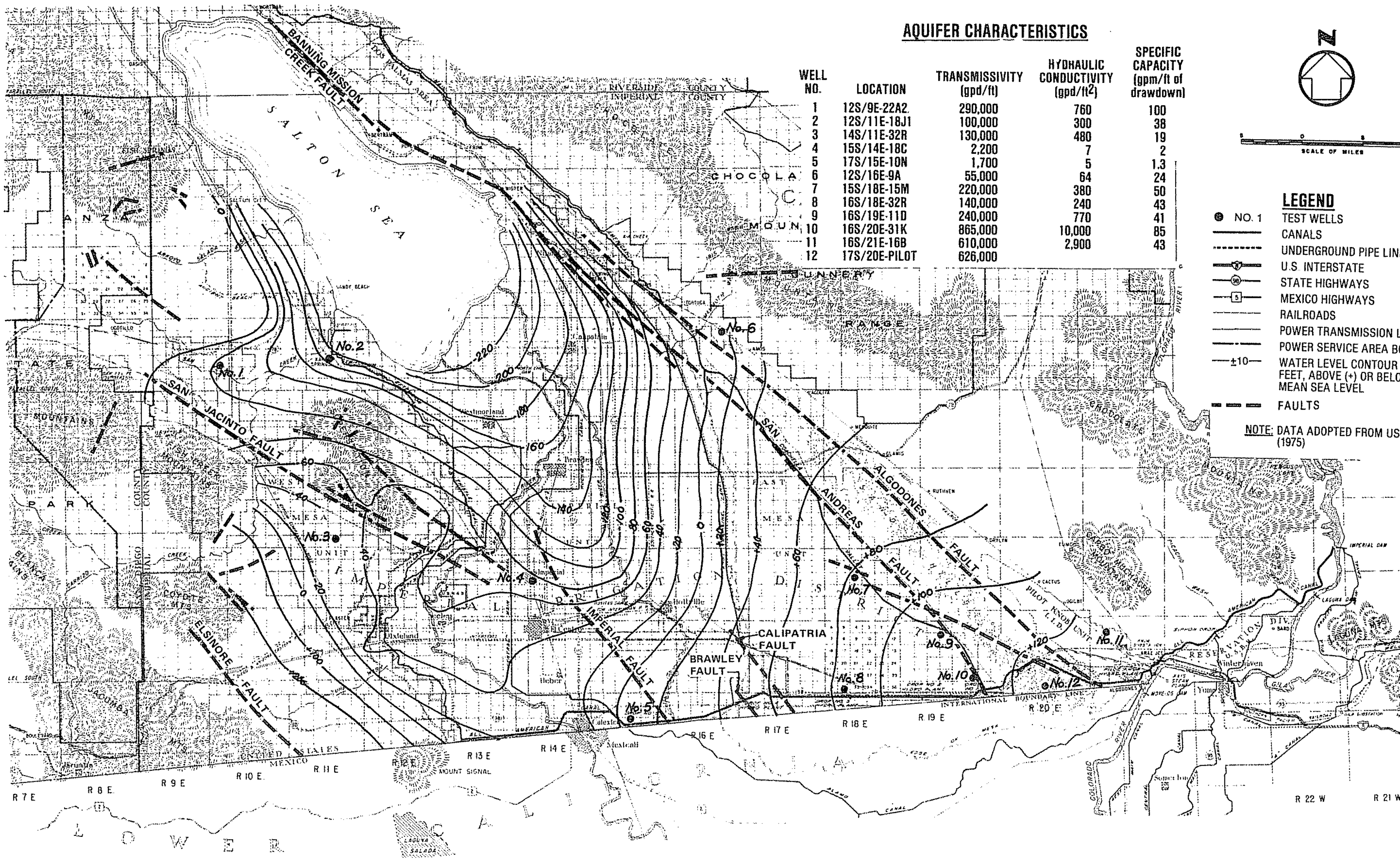
A. Groundwater Barriers

The San Andreas fault system has been recognized as the major strike-slip fault system that traverses the Salton Trough. The following subsystems of the San Andreas fault system (see Figure 3-2) have been discovered in the Imperial Valley:

(1) The San Andreas Fault lies along the northeast margin of the Imperial Valley. The Algodones Fault extends from the Salton Sea southeast beneath the Sand Hills and the East Mesa to the Colorado River south of Pilot Knob. The Calipatria Fault and the Brawley Fault trend northwest-southeast through the west and southwest portions of East Mesa.

(2) The Elsinore Fault is the southwesternmost fault of the San Andreas system. The Laguna Salada Fault, which lies mostly in Baja California, Mexico, is an extension of the Elsinore Fault. Both faults are at the southwest boundary of the Imperial Valley.

(3) The San Jacinto Fault of the San Andreas system begins in the San Gabriel Mountains (about 120 miles northwest of the Imperial Valley), extends southeast, and enters the Imperial Valley northwest of El Centro as the Imperial Fault.



WELL NO.	LOCATION	TRANSMISSIVITY (gpd/ft)	HYDRAULIC CONDUCTIVITY (gpd/ft^2)	SPECIFIC CAPACITY (gpm/ft of drawdown)
1	12S/9E-22A2	290,000	760	100
2	12S/11E-18J1	100,000	300	38
3	14S/11E-32R	130,000	480	19
4	15S/14E-18C	2,200	7	2
5	17S/15E-10N	1,700	5	1.3
6	12S/16E-9A	55,000	64	24
7	15S/18E-15M	220,000	380	50
8	16S/18E-32R	140,000	240	43
9	16S/19E-11D	240,000	770	41
10	16S/20E-31K	865,000	10,000	85
11	16S/21E-16B	610,000	2,900	43
12	17S/20E-PILOT	626,000		

Figure 3-2 - Groundwater Map
(1965 water table and test wells)
and San Andreas Fault System
(Parsons, 1985)

Numerous earthquakes and fault movements have been recorded. The 1983 LeRoy Crandall and Associates report indicated that disparities in water levels crossing the Calipatria and Brawley Faults are found to be as much as 10 ft. Consequently, it could be assumed that the faults crossing the aquifer will act as a partial barrier to groundwater movement. This assumption has been applied in the groundwater model studied by USBR (1985), although the degree of these barrier effects has not yet been well defined.

B. Groundwater Occurrence

Groundwater occurs under confined, unconfined, or semiconfined conditions in the area. Clay layers between overlying and underlying permeable layers restrict the free hydraulic connection between the aquifers, but only limited information is available on the continuity and areal extent of clay layers in the Imperial Valley area. Numerous small springs are found in a zone on the northeast side of the Salton Sea that roughly parallels the San Andreas fault system and is downgradient from the Coachella Canal (USGS, 1975). There are also several wells in the area under artesian conditions. This groundwater under confined conditions is moving under pressure caused by a difference in head between the recharge and discharge areas (Crandall, 1983).

The USGS (1975) has presented an extensive geohydrologic reconnaissance over the Imperial Valley area. Data on more than 300 wells was inventoried, including well depth, water depth, pumping tests, and water qualities. The location of test wells and the 1965 water level of the aquifer are shown on Figure 3-2. From the water level contour shown on the figure, it can be concluded that groundwater generally moves toward the axis of the valley and thence northwest toward the Salton Sea. The configuration of the contour lines also suggests that considerably less water moves toward the New River than toward the Alamo River. The relatively wide spacing of the contours is caused by the higher transmissivity in this region. In addition, appreciable quantities of groundwater move into the extensive system of drains in the irrigated area.

Water-level measurements in the area have been conducted by the District since 1940, and there are water-level records for 113 wells through 1985. The 1985 water-level contour of the East Mesa area is presented in Figure 3-3. More water-level contours of the East Mesa area for various years can be found in the Crandall report (1983).

C. Aquifer Characteristics

Pumping tests were conducted on 11 wells by USGS (1975) and one pilot well by USBR and BLM (1977) to obtain aquifer characteristics. The locations of the test wells are shown in Figure 3-2, which includes the table of aquifer characteristics.

The test data of the 11 USGS wells was analyzed by the nonequilibrium formula, and pilot well data was computed by both equilibrium and nonequilibrium formulas. The results of analysis indicate that, in the east and west Imperial Valley, moderate to high yields can be obtained because transmissivities of several hundred thousand gallons per day per foot are present in those areas.

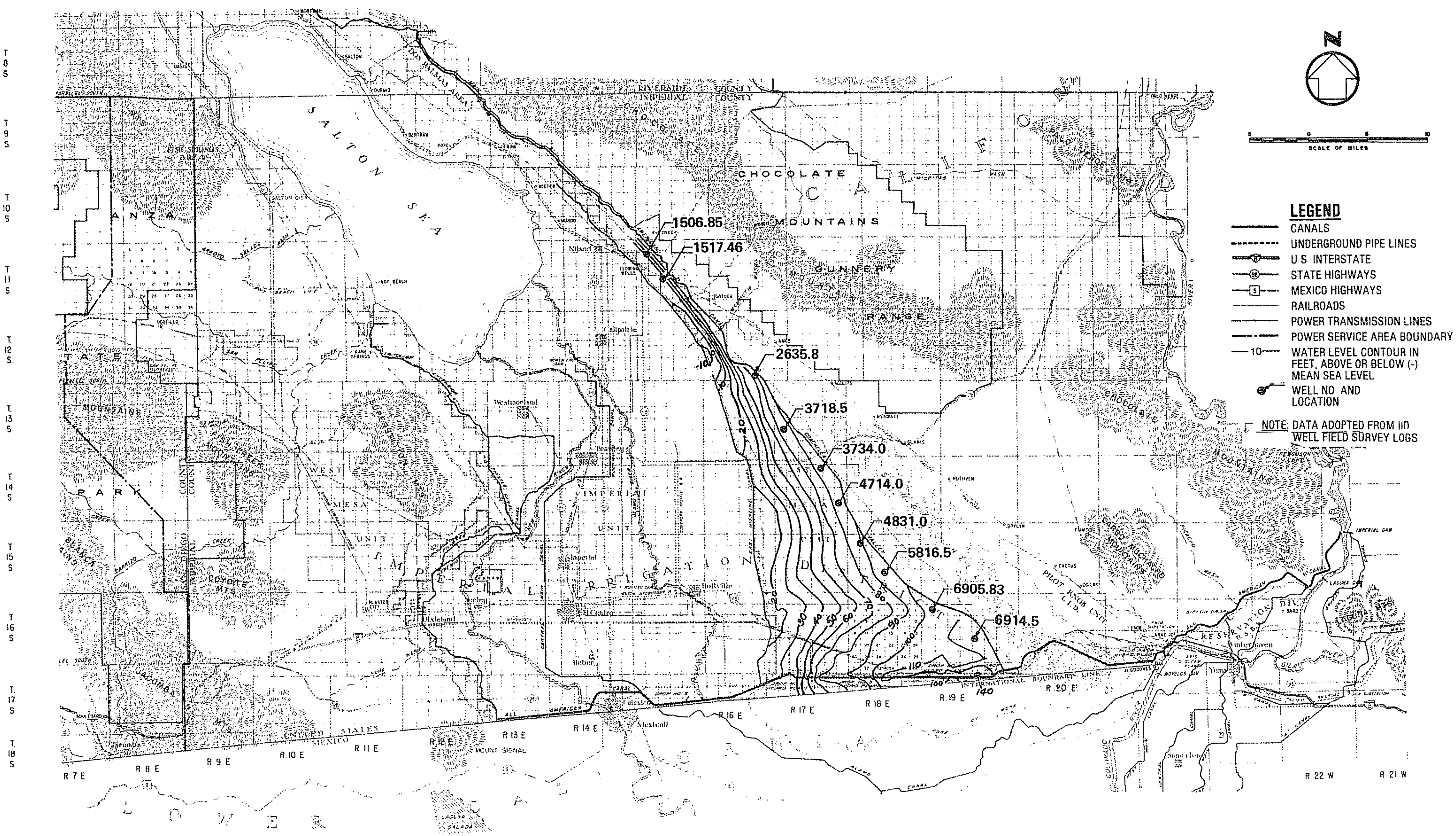


Figure 3-3 - 1985 East Mesa Groundwater Map and Well Locations along Coachella Canal (Parsons, 1985)

In the central Imperial Valley potential groundwater development is severely limited. Low yields of groundwater are expected because low transmissivities have been detected from two wells: No. 4 (15S/14E-18C) and No. 5 (17S/15E-10N). In general, the transmissivity is likely to be in the range of 1,000 to 10,000 gpd/ft to a depth of 500 ft, and it could be even lower at greater depths. The flatter water level in the southeastern position of East Mesa suggests higher transmissivities in this area, which are proved by the pumping tests at wells No. 9 (16S/19E-11D), No. 10 (16S/20E-31K), No. 11 (16S/21E-16B), and No. 12 (pilot).

No storage coefficients were computed by USGS (1975). However, it has been suggested that storage coefficients under unconfined conditions range from almost zero to a few hundredths for clay and silt, and from 0.2 to 0.4 for clean sand and gravel. When water is confined, storage coefficients generally range from about 0.00001 to 0.01; in the Imperial Valley area.

Based on the records of selected wells and springs (USGS, 1975), one may conclude that:

(1) Well yields in western Imperial Valley range from 3 to 1,450 gpm. High well yields apparently are at the lower West Mesa; the rate is over 1,400 gpm as identified by wells 12S/9E-22A2 and -23D. The well yields will decrease rapidly toward the southwest ends of West Mesa.

(2) In the central Imperial Valley, 42 well discharge records show very low well yields, ranging from 1 to 90 gpm.

(3) In the eastern Imperial Valley or the East Mesa area, higher well yields are suggested by Crandall (1983). The well near Holtville Airfield is reported to have a 3,000-gpm discharge. A well field planned by USBR and BLM (1977) near Drop No. 1 has shown that a production capacity of 2,800 gpm (6.33 ft^3/sec) can be easily achieved. In general, yields over 900 gpm could be accomplished in the East Mesa area with depths greater than 200 ft. Well 17S/17E-3C near Drop No. 4 of the All-American Canal has produced as much as 600 gpm in the upper 100 ft.

3.2.2 WATER QUANTITY

The most important source of groundwater recharge in the Imperial Valley is the Colorado River water through irrigation and leakage from numerous unlined canals. Other sources of recharge, considered minor, are underflow from tributary areas and infiltration of precipitation and runoff.

As noted in USGS (1975), the leakage caused groundwater ridges to form beneath the canals almost immediately, and in time the top of the ridges intercepted the canals. The leakage also spread horizontally, causing water levels to rise over large areas. Crandall (1983) detailed the history of the rise in water levels and indicated that water levels farther north in the area stabilized around 1965. A comparison of the 1985 water table (Figure 3-3) and the 1942 water table (Figure 3-4) suggests that the rise in water levels decreases gradually from about 40 ft in the northeast end of Imperial Valley to less than 10 ft near the East Highline Canal.

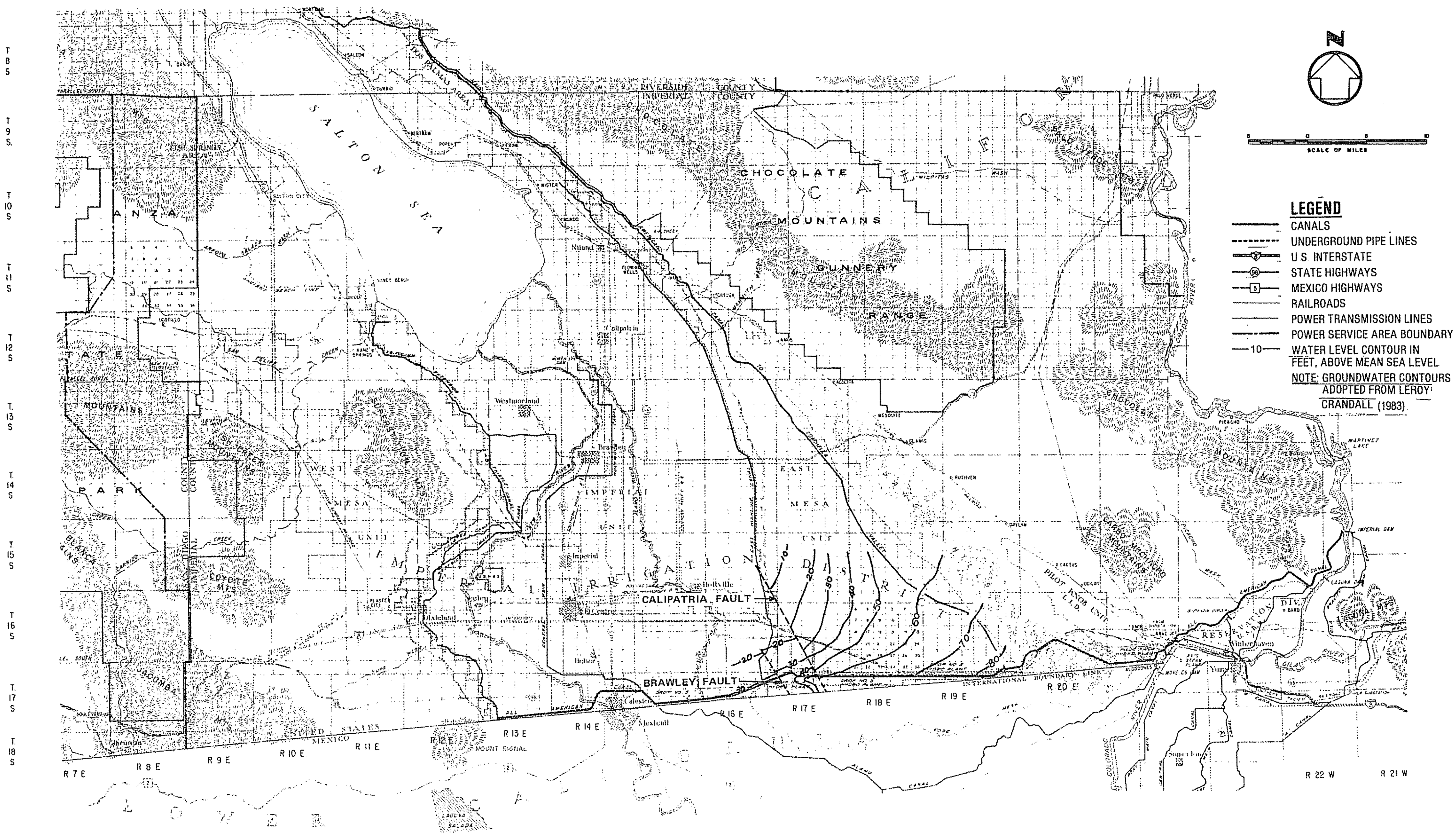


Figure 3-4 - 1942 East Mesa Groundwater Map (Parsons, 1985)

Available IID well records (1977 to 1985) show that cyclic water-level fluctuations occur annually or seasonally in wells adjacent to and in the vicinity of the All-American and East Highline Canals. Higher fluctuations are present along the canals and decrease in magnitude in both directions away from the canals. These fluctuations could be the results of the seepage variations induced by the fluctuations of canal flow rates. For example, the IID records of wells adjacent to the All-American Canal show that the maximum fluctuation differences (between highest and lowest water levels) vary from 0.9 to 9 ft. The higher variation of level differences may be the results of distance of wells from canal, aquifer characteristics, and amount of seepage. The extensive drainage system (i.e., subdrains in the irrigated area) in the central Imperial Valley prevents further increases in groundwater storage. It is believed that the water levels are stabilized unless local fluctuations occur as a result of areal irrigation.

As additional evidence of the effect of canal seepage on groundwater levels, the results of lining the Coachella Canal strongly indicate a direct cause-and-effect relationship. Table 3-16 presents the groundwater table elevations during the period beginning soon after completion of Coachella Canal lining (1981) and ending in 1985. (The wells used to collect this data are shown on Figure 3-3.) The table indicates a definite downtrend in groundwater elevation as a result of lining the Coachella Canal and thereby curtailing seepage recharge. The exception to this trend occurred at Well 6914.50 nearest to the All-American Canal where seepage recharge effects are still strong.

Table 3-16 - Groundwater Elevations along Coachella Canal

Well No.	Groundwater Elevation (ft)		
	1981	1985	Difference
1506.85	48.90	46.01	-2.89
1517.46	50.20	47.31	-2.89
2635.80	92.10	80.70	-11.40
3718.50	72.90	72.90	0.00
3734.00	93.80	84.30	-9.50
4714.00	88.80	82.06	-6.74
4831.00	100.64	89.34	-11.30
5816.50	99.80	93.50	-6.30
6905.83	107.70	101.70	-6.00
6914.50	111.30	116.09	+4.79

Source: Parsons, 1985.

A. Aquifer Yield

After reviewing the available information and examining the aquifer characteristics, it could be concluded that both the eastern Imperial Valley and the western Imperial Valley have the potential to be developed as groundwater well fields.

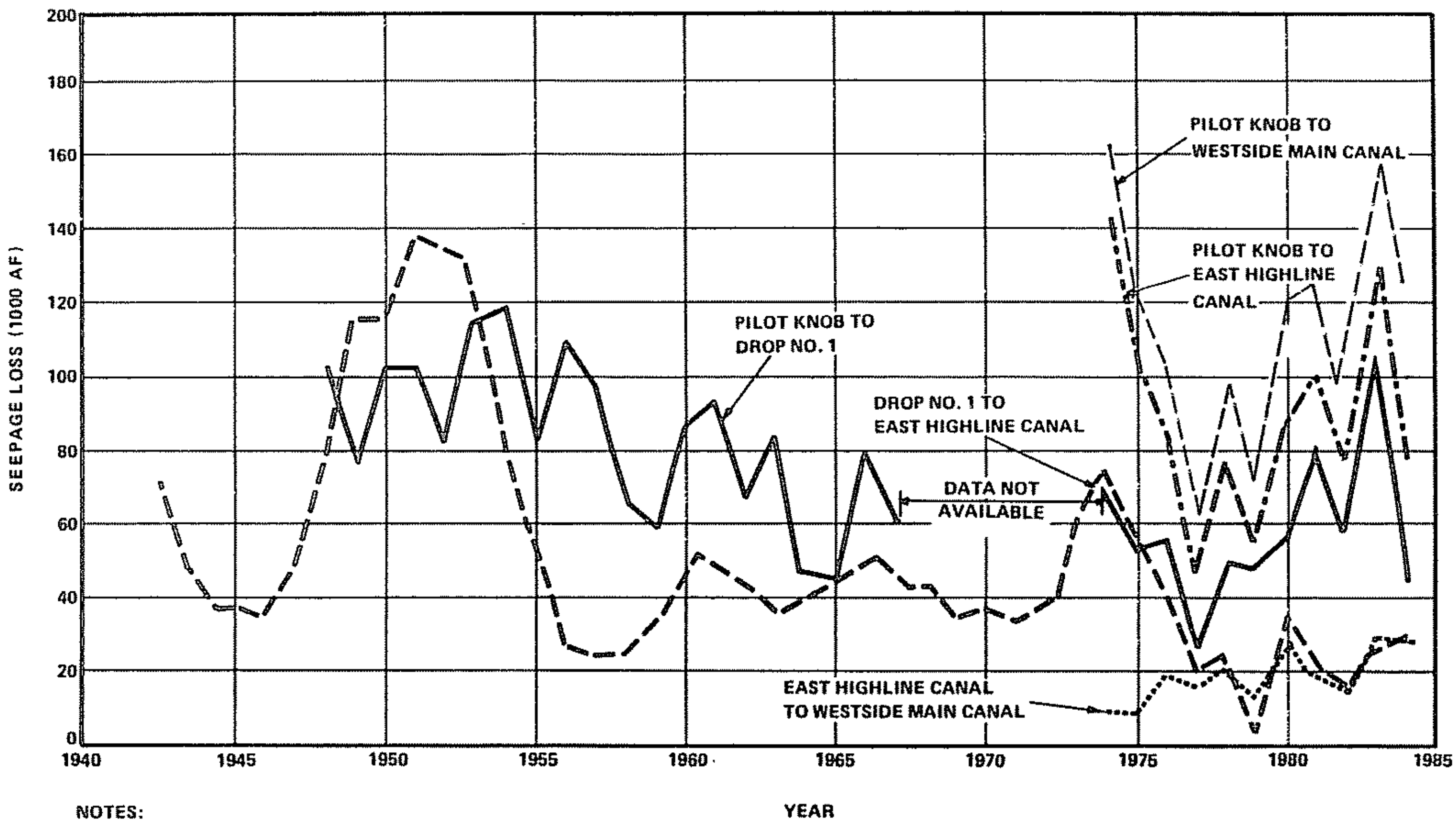
The eastern Imperial Valley (East Mesa) probably has greater potential for groundwater development than other portions of the project area, especially along the All-American Canal because of the substantial recharge caused by canal leakage. Crandall (1983) has estimated the potentially recoverable water to be about 700,000 AF from groundwater storage at the East Mesa area, and recently in a draft report prepared by the U.S. Bureau of Reclamation (USBR, 1985a) the preliminary finding on East Mesa groundwater storage was:

> "... This gives a volume of pumpable Colorado River quality water of 2,000,000 acre-feet, which is believed to be a conservative estimate."

Since this is as yet a preliminary determination, the extremely conservative 700,000-AF estimate will be used until the draft USBR report is finalized.

The Crandall (1983) computation was based on the change in storage methodology used by the State Water Rights Board (City of Los Angeles vs. City of San Fernando, 1962). Eleven subareas were divided on the basis of similar specific yields, which were predetermined using the method developed by CDWR and were related to various types of alluvial deposits. Also, the computation considered the recovery of increasing groundwater storage since 1942.

Seepage from the All-American Canal is the main source of groundwater recharge for the East Mesa groundwater basin. Until the lined Coachella Canal was completed in 1980 (replacing an unlined canal), seepage from this source was also a major contributor to groundwater recharge in the East Mesa zone. However, since 1980, recharge has been essentially derived from All-American Canal seepage. Because the rate of leakage from the canal cannot be determined precisely, the method used to estimate the canal seepage loss by USGS (1975) and Crandall (1983) will also be adopted hereafter. Discounting the evaporation losses in selected reaches of the All-American Canal (6-ft annual evaporation loss is assumed) and vegetative losses from the IID's yearly water report gives an estimate of the annual seepage losses. The trend of the annual water-loss hydrographs (Figure 3-5) shows that the seepage losses are decreasing and tend to stabilize with less yearly fluctuation. From the analysis of 10 years of records (1975 to 1984), the average annual seepage rates from the All-American Canal (for reaches Pilot Knob to Drop No. 1 and from Drop No. 1 to the East Highline Canal) are approximately 57,000 and 26,000 AF/year, respectively, or a total of about 83,000 AF/year of seepage losses from Pilot Knob to the East Highline Canal. These estimates are slightly higher than the results of the USBR (1985) All-American Canal groundwater model. For example, about 71,000 AF/year seepage losses during 1984, estimated from the hydrograph for the reach from Station 1117 to the East Highline Canal, compares to about 64,000 AF/year from the model simulation. The seepage rate for the reach from the East Highline Canal to the



NOTES:

1. WATER LOSSES DATA OBTAINED FROM IID YEARLY WATER REPORT (1974 - 1984).
2. WATER LOSSES DATA BEFORE 1974 ADOPTED FROM LEROY CRANDALL ASSOCIATES (1983) AND USGS (1975).

Figure 3-5 - All-American Canal Hydrograph of Water Losses (Parsons, 1985)

Westside Main Canal is about 18,000 AF/year (based on the average of 10 years of records, 1975 to 1984). Therefore, a total of 101,000 AF/year seepage loss from Pilot Knob to the Westside Main Canal will be expected.

Underflows from tributary areas contribute most of the recharge to the groundwater basin of western Imperial Valley, most probably from West Mesa. The underflows have been estimated by USGS (1975) to be about 7,000 AF/year groundwater inflow from Mexicali Valley through a section that extends westward from Calexico to the mountains, a distance of about 12 miles. The underflow beneath San Felipe Creek, northwest of the project area, is about 10,000 AF/year. Underflows from Coyote Wash and Pinto Wash are considered to be insignificant.

In the central Imperial Valley, the underflows from the East Mesa and the West Mesa of 54,000 AF/year (about 26 miles boundary length at a water table gradient of 10 ft/mile for high reach, and about 12 miles boundary length at a water table gradient of 30 ft/mile for low reach) and 15,000 AF/year (about 22 miles boundary length at a water table gradient of 10 ft/mile), respectively, are simply estimated from the Darcy Equation, where the transmissivities were assumed to be 110,000 gpd/ft (high reach), 55,000 gpd/ft (low reach), and 60,000 gpd/ft with respect to the boundaries between the central Imperial Valley and East Mesa, as well as West Mesa. The seepage water from the East Highline Canal or partial underflow from the East Mesa is intercepted by the drains that parallel the East Highline Canal. The average annual water recovery is about 17,500 AF based on District records from 1974 to 1984. The average annual seepage water recovery from the existing seepage recovery system (Drop No. 1 to central main check) for the All-American Canal is about 25,000 AF as indicated in the USBR (1984) report. By applying the calculated rate of 820 AF/year per linear mile of canal, approximately 45,000 AF/year of seepage recovery water could be estimated if a seepage recovery system is to be installed along the All-American Canal from Pilot Knob to the Westside Main Canal.

The groundwater flow to Mexico has been discussed by Crandall (1983). It is believed that a substantial amount of groundwater flow occurs across the border into Mexico because of the pumping at Andrade Mesa and in the Mexicali Valley. This flow of groundwater might be reduced or even reversed if the entire All-American Canal were lined (USBR, 1985). This issue will be discussed in subsection 3.2.4.

B. Well Fields

The well field with greatest potential for development would be located in the East Mesa area, especially along the All-American Canal. Two well fields capable of producing 10,000 AF/year of groundwater have been proposed near Drop No. 1 on the All-American Canal:

(1) Between Interstate Highway 8 and the Mexican International Boundary (USBR and BLM, 1977).

(2) The east side of the sandhills, east of Drop No. 1 (USBR, 1985).

Both locations indicate that there would be no problem to supply 10,000 AF/year of water from either well field. This pumping could induce extra seepage from the All-American Canal (about 1,000 AF/year).

More well fields could be developed from Drop No. 1 of the All-American Canal to the East Highline Canal; however, further test well observations are required to determine physical quantities of these well fields. In addition, the western Imperial Valley, West Mesa, could be another potential well field. Final determination of development feasibility at these other locations will require more field work.

3.2.3 WATER QUALITY

The chemical qualities of the groundwater in the area vary widely; saline waters present obvious problems in this groundwater basin. In general, deeper aquifers show higher salinity than the shallower ones. The reasons for saline water are probably:

(1) The deeper groundwater may be moderately altered connate ocean water.

(2) The shallower groundwater has accumulated salts from storm runoff and irrigation leaching of soluble evaporates from sedimentary soils above the water table.

In addition, the salinity of Colorado River water delivered to Imperial Valley for irrigation has increased. Normally, saline water is not favorable for irrigation or domestic uses.

More than 200 groundwater samples from wells in the project area have been analyzed (USGS, 1975). The samples were taken from different depth intervals, from about 25 ft below the surface to more than 1,000 ft. In that report, histories, backgrounds, analyses, and some conclusions concerning the grondwater samples have been discussed in detail. Using the data, the TDS contour lines are plotted on Figure 3-6, which is based on the average TDS of each well for all depths.

Beneath most areas in the central Imperial Valley, the groundwater contains dissolved solids that make it unsatisfactory as either a domestic or an irrigation supply. The highest concentration of TDS can be found in the central area, about 15,200 mg/L at well 12S/14E-21J at a depth of about 150 ft. Moreover, the TDS map shows that TDS of groundwater in the central Imperial Valley is over 5,000 mg/L. A small area, located at the southeast side of the central valley and adjacent to the East Highline Canal, has TDS less than 1,000 mg/L.

Part of eastern Imperial Valley probably has a greater potential for groundwater development. Figure 3-6 indicates that only the southern small portion adjacent to the All-American Canal has a TDS content of less than 1,000 mg/L, especially in the Pilot Knob Mesa and the sandhills areas. Water quality data from well pumping tests for the well fields proposed by USBR (1985) and USBR and BLM (1977) at the East Mesa near Drop No. 1 of the All-American Canal had TDS from 600 mg/L to 870 mg/L. The groundwater in the

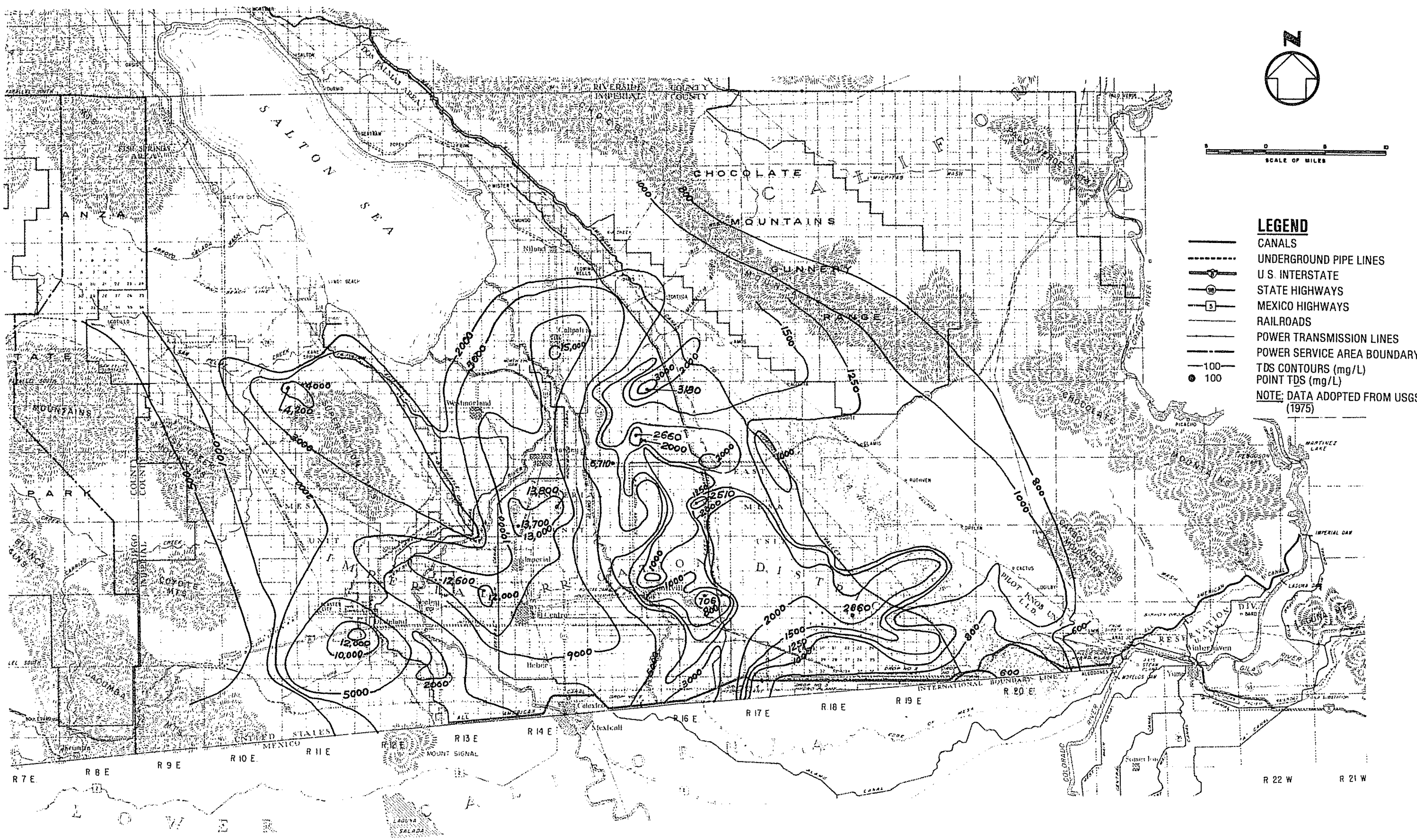


Figure 3-6 - Groundwater TDS Map
(Parsons, 1985)

area is a sodium sulfate type - the same as Colorado River water in the All-American Canal. More chemical characteristics of groundwater in the East Mesa area are discussed by Crandall (1983). Two zones relating to different depths were considered: Zone A is from 85 to 160 ft, and Zone B is from 0 to 85 ft. The water qualities of Zone A and Zone B are summarized in Table 3-17.

Table 3-17 -- Groundwater Quality: Zone A vs. Zone B
(East Mesa area)

	Zone A (85 to 160 ft)		Zone B (0 to 85 ft)	
Chemical Character	Sodium chloride	15 wells	Sodium chloride	13 wells
	Sodium sulfate	3 wells	Sodium sulfate	10 wells
	Sodium bicarbonate	0	Sodium bicarbonate	6 wells
pH	Range: 7.4 - 8.6	(17 wells)	Range: 4.3 - 11.2	(27 wells)
	Common: 7.4 - 8.6		Common: 6.9 - 9.0	
	4.3 - 6.4	0	4.3 - 6.4	4 wells
	6.5 - 7.5	1 well	6.5 - 7.5	5 wells
	7.6 - 8.6	16 wells	7.6 - 8.6	11 wells
	8.7 - 9.7	0	8.7 - 9.7	3 wells
	9.8 - 11.2	0	9.8 - 11.2	4 wells
TDS (ppm)	Range: 589 - 2,860	(17 wells)	Range: 250 - 2,620	(27 wells)
	Common: 750 - 995	9 wells	Common: 434 - 787	16 wells
	589	1 well	250	1 well
	1,270	1 well	882 - 1,413	7 wells
	1,710 - 2,860	6 wells	1,750 - 2,620	3 wells
	7,112	(1 well)[a]	7,151	(1 well)[a]
Fluoride (ppm)	Range: 0.2 -14	(10 wells)	Range: 0.1 - 1.6	(22 wells)
	1.9	(1 well)[a]	3.0	(1 well)[a]
Boron (ppm)	0.26 and 0.46	(2 wells)	0.41	(1 well)

[a]Not included in the range of values.
Source: after Crandall, 1983.

The general mineral analyses indicate that groundwater in Zone A is probably more representative of the natural groundwater in the East Mesa and probably has not been affected much by seepage of the canals. For comparison, the TDS content of groundwater in Zone A commonly varies from 750 to 995 ppm, based on water samples for nine wells, which is similar to the TDS of Colorado River water.

The general mineral analyses indicate that groundwater in Zone B is characterized by sodium chloride and sodium sulfate. Eight of the wells with sodium sulfate water are located along the All-American Canal, and two are located along the Coachella Canal. The data clearly indicates the effect of canal seepage (sodium sulfate water) on groundwater along the canal. Six wells, five along the All-American Canal and one along the East Highline Canal, are sodium bicarbonate. The TDS content of groundwater in the shallow zone commonly varies from 434 to 787 ppm and is lower than the deeper Zone A. The range of values is the same as along the All-American Canal.

In the western Imperial Valley, the chemical characteristics of groundwater vary from area to area or even from well to well. In general, the map indicates that the TDS content of the groundwater increases eastward toward the central Imperial Valley. The concentration of TDS higher than 3,000 mg/L is located at the northeast part of western Imperial Valley, probably over the area at the north side of the San Jacinto Fault.

The well field at the Coyote Valley is the main area in the western Imperial Valley, south of San Felipe Creek, where development of groundwater has been significant and where most wells yield soft bicarbonate water containing less than 400 mg/L dissolved solids. However, TDS of 12,200 mg/L is found in well 16S/11E-23B in the Yuha Desert, south of Interstate 8. The average of 2,000 mg/L TDS with sodium sulfate is considered representative over the general area of the West Mesa and the Yuha Desert. This water is not considered satisfactory for irrigation use without treatment.

3.2.4 LEGAL CONSIDERATIONS

On the basis of legal review of the IID right to pump groundwater within District boundaries, it is the opinion of counsel that:

> "The Imperial Irrigation District has a right to recapture seepage and wastewater which has leaked out of its canals, diversion systems and irrigated fields while it is within the district boundaries. Users of the flow downgradient from the Imperial Irrigation District have established no right to have that flow continue. Therefore, a conservation program involving the recapture of such seepage water is well within the rights of the Imperial Irrigation District.
>
> "Mexico's right to the waters of the Colorado River, whether in the original bed or as return flow from the Imperial Irrigation District, are, we believe, set by established treaties and are part of the Law of the River. We do not believe that Mexico can increase its use of Colorado River by claiming rights to return flow of that water once it leaves Imperial Irrigation District."

3.2.5 SUMMARY

The analysis has shown that groundwater is abundant throughout the District with higher TDS found in the peripheral areas. This groundwater is not generally usable without some desalination; nevertheless, desalination of mildly saline water may be economically feasible and will be investigated in subsequent chapters as a means of conserving Colorado River water. Moreover, in specific areas (East Mesa) untreated water can be used. Use of this resource will be discussed later when the various conservation options are compared.

3.3 OTHER SOURCES

In addition to the Colorado River, three other surface water sources will be reviewed primarily to ensure that no aspect of water resource analysis has been neglected. A discussion follows of these secondary sources: the New River, the Alamo River, and the Salton Sea.

3.3.1 NEW RIVER

The New River is a perennial river flowing from Mexico, near Calexico. The perennial flows are maintained at the border by agricultural runoff and municipal discharges in Mexico. The mean flow at the border is over 200 ft^3/sec. The water is already heavily contaminated both with municipal wastes and agricultural wastewater. The TDS is high, and fecal coliforms are very high. This water is essentially unusable as a source for irrigation or municipal use unless it is put through extensive desalination and other treatment processes.

As the New River flows through Imperial Valley it receives additional runoff, primarily from irrigated farmland. The flow at the outlet to the Salton Sea, thus averages over 700 ft^3/sec. The salinity and other water quality parameters are improved as a result of dilution by water with lower salinity and less contamination. The fecal coliform averages 4,133 MPN/100 mL as opposed to 5,154,300 MPN/100 mL at the border. More information on water quality is presented in subsection 6.1.1.

The New River is one of the major contributors of inflow to the Salton Sea. Its contribution to the water balance is presented in Table 5-1. The 1975-1984 average inflow is 442,700 AF/year. This represents approximately 38% of the IID contribution of inflow to the sea.

3.3.2 ALAMO RIVER

The Alamo River has a hydrologic regime similar to that of the New River. The difference lies in the very small inflow from Mexico at the International Border. The mean flow is only 2.2 ft^3/sec and ranges from 1 to 4 ft^3/sec. The water quality of this incoming water is of better quality than that of the New River at the border. Salinity is lower (conductivity = 5,980 umho/cm, TDS = 3,482 mg/L) as are other pollutant indicators, e.g., BOD = 6.1 mg/L and fecal coliform = 98,547 MPN/100 mL.

Although the Alamo River has a much lower flow than the New River at the border, it has a significantly higher flow at the outlet to the Salton Sea. It thus receives a larger portion of the irrigation runoff within IID. Table 3-18 presents the summary hydrologic and water quality data for the Alamo River at the outlet to the Salton Sea. This data shows considerably better water quality than that of the New River. More data for 1983 to 1984 is shown in Chapter 6 for TDS, conductivity, and pH.

Table 3-18 - Hydrologic and Water Quality Data: Alamo River at the Outlet to the Salton Sea[a]

Parameter (unit)	Mean	Minimum	Maximum
Flow (ft^3/sec)	860	779	992
Conductivity (umho/cm)	3,640	3,640	3,640
DO (mg/L)	7.5	5.6	8.6
BOD, 5-day (mg/L)	5.8	3.9	9.0
COD (mg/)	30.7	22	36
pH	7.8	7.7	8.0
Fecal coliform (MPN/100 mL)	11,167	2,200	28,000
Total dissolved solids (mg/L)	2,749	2,600	2,828

[a]Storet station number WB070506; period of record 1984-1985.
Source: Parsons, 1985, after data from Storet.

The contribution of the Alamo River to the water balance of the IID is shown in Table 5-1. The average inflow to the Salton Sea via the Alamo River between 1975 and 1984 is 606,000 AF/year. This is approximately 53% of the contributing inflow from IID. The Alamo River thus represents a very sizable water resource. The problem of high salinity is the major obstacle to use as a direct water supply; however, careful mixing with other freshwater supplies and selected treatment such as desalination could make this a viable resource. This was demonstrated recently by a cooperative study conducted by the USDA, when Alamo River water mixed with canal water was applied successfully to selected crops in the Imperial Valley.

3.3.3 SALTON SEA

A. Historical Conditions

The Salton Sea is a lake formed in an internally drained basin. It is thus a natural sump and is sustained primarily from agricultural runoff from both the Imperial and Coachella Valleys. The Salton Sea was formed initially in 1905-1907 when the Colorado River was breached near Yuma and flowed unimpeded into the Salton Trough. The initial filling period was followed by a period of sharp decline before irrigation return flows increased to the point where the level of the sea gradually increased. The sea is thus recognized as a depository for irrigation waste. A series of land withdrawals by the federal government resulted in the withdrawal of all public land below elevation -220 ft for this purpose.

The salinity of the Salton Sea has been generally increasing over the life of the sea. The initial salinity is a result of the dissolution of salts within the sea floor. The continued rise in the salinity is a result of the inflow of water with fairly high TDS and the very high evaporation. The only outflow is by evaporation. Thus, the salinity is a function of the degree to which inflow balances outflow. In years of very high inflow, the salinity of the sea may decrease because the evaporation is significantly less than the diluting effect of the inflow. The present-day salinity is approximately 40,000 ppm.

The historical change in elevation and salinity of the sea is shown in Figure 5-1. The variation in elevation and salinity is dependent on the natural variation in evaporation, direct rainfall and storm runoff, and the manmade variation in the irrigation return flows. The general trend, however, has been an increase in both the elevation of the sea and its salinity.

The historical Salton Sea water budget is presented in Table 5-7 for years 1950-1984. The average inflow to the sea during this period was approximately 1,368,000 AF/year. Direct rain to the sea contributes another 44,500 AF/year, and water loss is approximately 1,326,000 AF/year via evaporation. The elevation of the sea thus increased from -240.2 ft in 1949 to -226.7 ft in 1984.

The salinity of the sea has increased as a result of evaporation in addition to the inflow of salt. Many estimates of salt loading have been made and range from 3.67 to 5.04 million tpy as shown in Table 3-19. These figures demonstrate an increase in salt input in recent years. The average of all these figures is approximately 4.27 million tpy.

Table 3-19 - Historic Salt Loading: Salton Sea

Salt Loading (million tpy)	Time Period
3.95[a]	1948-1962
3.67[b]	1945-1963
4.44[a]	1963-1972
5.04[c]	1963-1980

[a]U.S. Department of the Interior and the State of California Resources Agency, 1974b.
[b]Hely et al., 1966.
[c]USBR, 1981.
Source: Parsons, 1985.

The IID is the largest contributor of flows to the Salton Sea. Other flows come from Mexico via the New and Alamo Rivers, the Coachella Valley, and miscellaneous other flows, including washes flowing directly to the sea. The distribution of inflow is presented in Table 5-8. This historical data shows several trends:

(1) The contribution from the IID has decreased in recent years. The present-day inflow is running at about 810,000 AF/year, a significant decrease from the 33-year average of 994,000 AF/year.

(2) The input from Mexico has increased steadily in recent years to its present level of around 250,000 AF/year.

(3) The inflow from the Coachella Valley also increased but is now fairly stable at about 208,000 AF/year. The remaining inflow is more variable, reflecting the variation in rainfall and runoff patterns. The long-term average for this period is 95,000 AF/year.

B. Future of Salton Sea

The future of the Salton Sea is dependent on future inflows and the salinity of the incoming water. As long as an inflow is maintained, there will be a Salton Sea. However, the volume of the sea may change dramatically, affecting the level of the sea and its salinity. In developing projections of the elevation and salinity of the sea, the following assumptions were made on the basis of observations of the historical inflows to the sea:

(1) The contribution from IID has been reduced in recent years to its present level of about 810,000 AF/year. This was the average for the period 1982-1984 and was assumed to be the baseline contribution from the IID.

(2) The historical contribution from the Coachella Valley has been fairly stable at about 208,000 AF/year. This was the average for the period 1982-1984 and was assumed to remain constant. This average was therefore used to model future inflows from Coachella.

(3) Although the historical inflow from storm runoff and other sources is variable, the long-term average for the years 1950-1984 was assumed to represent a reasonable quantity for this category (95,000 AF/year).

(4) Long-term average direct rainfall and evaporation were used (0.1943 ft/year and 5.789 ft/year, respectively).

(5) The inflow from Mexico via the New and Alamo Rivers has increased dramatically in recent years to about 250,000 AF/year. This is likely a result of increased diversion of Colorado River water and use in Mexico for irrigation. This number was thus used as a starting point; however, it was also assumed that excess Colorado River water would not be as prevalent in the future. The flow from Mexico was thus decreased over a 5-year period beginning in 1987 to a sustained flow of 160,000 AF/year (Case 1) and 200,000 AF/year (Case 2).

(6) The historical salt loading has been estimated by several authors. For this analysis, the worst case of approximately 5 million tpy was used from the USBR estimate for the period 1963-1980 (USBR, 1981). This position was taken because the Colorado River's salinity is expected to increase, causing in turn increased leaching.

(7) The area-capacity curves used in this analysis were those used by the USBR in its Salton Sea Operation Study (USBR, 1981).

The eight total conditions analyzed are given in Table 3-20.

Table 3-20 - Summary of Conditions Analyzed (AF/year)

Condition	Flow Reduction to Salton Sea	New River Inflow from Mexico	
		Case 1	Case 2
Baseline	0	160,000	200,000
Scenario 1	100,000	160,000	200,000
Scenario 2	200,000	160,000	200,000
Scenario 3	300,000	160,000	200,000

Source: Parsons, 1985.

The assumptions used to model the future elevations of the Salton Sea were tested by running the model against the historical change in elevation. The calibration was run using long-term averages for inflow, rainfall, and evaporation. The results of this calibration are shown in Figure 3-7. The model shows a good fit to the historical data with a correlation coefficient of 0.95. Based on these results, this model was used to project future elevations using the assumptions discussed above.

1. Case 1. The results of the baseline model are shown in Table 3-21. The only change in inflow would result from the decreasing flow from Mexico. By the year 2010, the elevation of the sea would decrease to about -231 ft and the salinity would increase to about 63,000 ppm. As this table shows, the salinity of the sea would continue to rise in the next 25 years, regardless of what the IID would accomplish in the way of water conservation.

Projected elevations and salinities of the Salton Sea under future conservation programs are shown in Tables 3-22 through 3-24; elevations are shown in Figure 3-8. Three scenarios were modeled ranging from a moderate

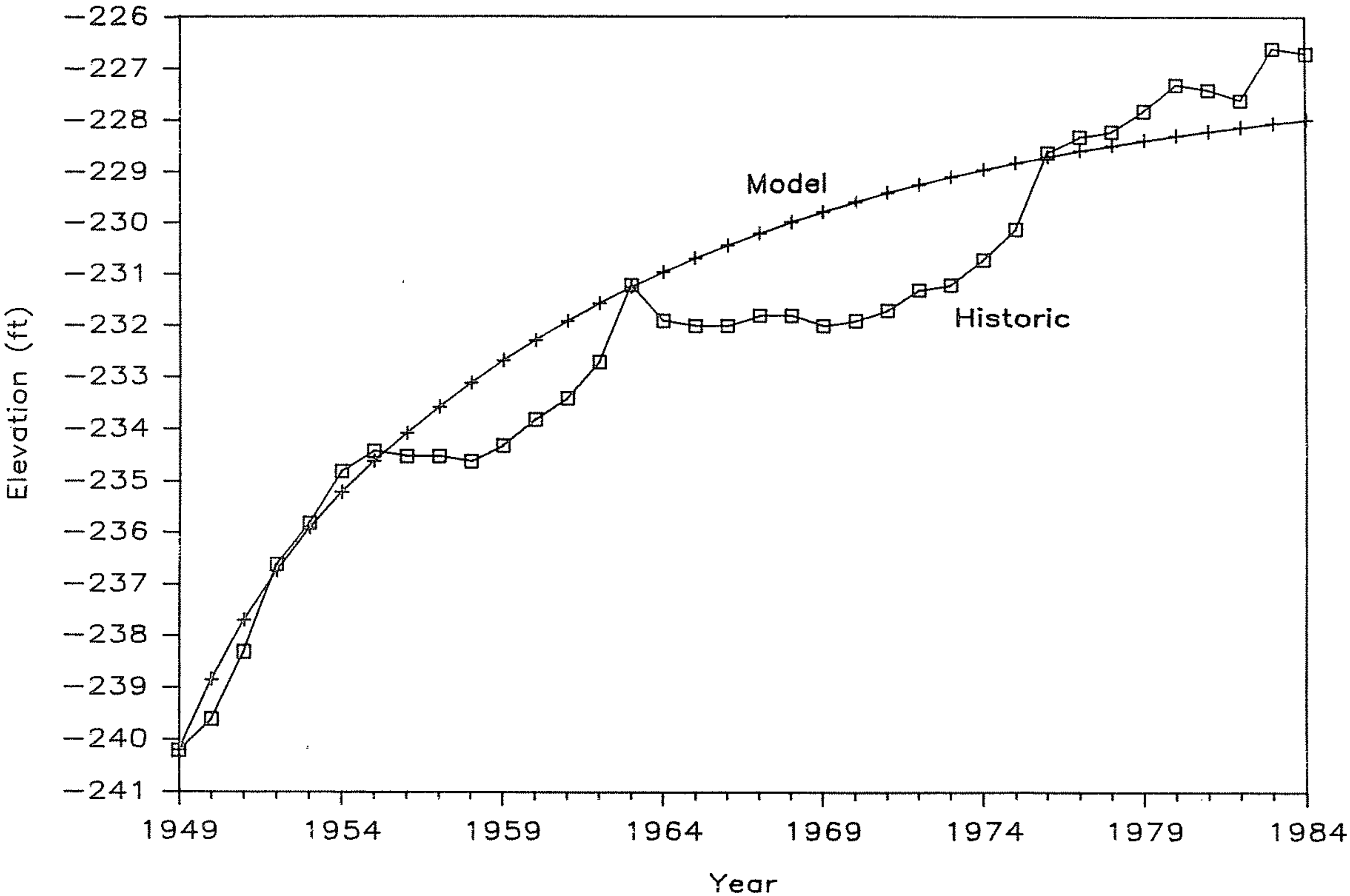


Figure 3-7 - Historic Salton Sea: Model Calibration
(Parsons, 1985)

Table 3-21 - Case 1: Salton Sea Future Elevations and Salinities
(baseline - no conservation)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (1,000 AF)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,363.00	47.68	1,420.57	-9.89	250.00	0.00	40,902
1987	-226.78	245.27	7,277.31	1,345.00	47.66	1,419.87	-27.21	232.00	0.00	41,462
1988	-226.89	244.94	7,250.09	1,327.00	47.59	1,417.94	-43.35	214.00	0.00	42,125
1989	-227.07	244.49	7,206.74	1,309.00	47.49	1,414.87	-58.38	196.00	0.00	42,889
1990	-227.31	243.69	7,148.36	1,291.00	47.35	1,410.73	-72.38	178.00	0.00	43,753
1991	-227.61	242.81	7,075.98	1,273.00	47.18	1,405.60	-85.43	160.00	0.00	44,720
1992	-227.96	241.76	6,990.55	1,273.00	46.97	1,399.55	-79.57	160.00	0.00	45,793
1993	-228.29	240.79	6,910.98	1,273.00	46.78	1,393.91	-74.12	160.00	0.00	46,852
1994	-228.60	239.88	6,836.85	1,273.00	46.61	1,388.66	-69.05	160.00	0.00	47,898
1995	-228.89	239.03	6,767.80	1,273.00	46.44	1,383.76	-64.32	160.00	0.00	48,930
1996	-229.16	238.25	6,703.49	1,273.00	46.29	1,379.20	-59.91	160.00	0.00	49,947
1997	-229.41	237.51	6,643.57	1,273.00	46.15	1,374.96	-55.81	160.00	0.00	50,951
1998	-229.64	236.83	6,587.76	1,273.00	46.02	1,371.00	-51.99	160.00	0.00	51,941
1999	-229.86	236.19	6,535.78	1,273.00	45.89	1,367.32	-48.43	160.00	0.00	52,917
2000	-230.07	235.60	6,487.35	1,273.00	45.78	1,363.89	-45.11	160.00	0.00	53,878
2001	-230.26	235.05	6,442.24	1,273.00	45.67	1,360.69	-42.02	160.00	0.00	54,826
2002	-230.44	234.53	6,400.22	1,273.00	45.57	1,357.71	-39.14	160.00	0.00	55,761
2003	-230.61	234.05	6,361.08	1,273.00	45.48	1,354.94	-36.46	160.00	0.00	56,682
2004	-230.76	233.61	6,324.61	1,273.00	45.39	1,352.35	-33.96	160.00	0.00	57,590
2005	-230.91	233.19	6,290.65	1,273.00	45.31	1,349.95	-31.64	160.00	0.00	58,485
2006	-231.04	232.80	6,259.01	1,273.00	45.23	1,347.71	-29.47	160.00	0.00	59,368
2007	-231.17	232.44	6,229.54	1,273.00	45.16	1,345.62	-27.45	160.00	0.00	60,239
2008	-231.29	232.11	6,202.09	1,273.00	45.10	1,343.67	-25.57	160.00	0.00	61,099
2009	-231.40	231.79	6,176.52	1,273.00	45.04	1,341.86	-23.82	160.00	0.00	61,947
2010	-231.50	231.50	6,152.69	1,273.00	44.98	1,340.17	-22.19	160.00	0.00	62,784

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 160,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-22 - Case 1: Salton Sea Future Elevations and Salinities - Scenario 1
(conservation of 20,000 AF/year to a total of 100,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,343.00	47.68	1,420.57	-29.89	250.00	-20.00	40,902
1987	-226.87	245.03	7,257.31	1,305.00	47.61	1,418.45	-65.84	232.00	-40.00	41,577
1988	-227.13	244.22	7,191.46	1,267.00	47.45	1,413.79	-99.33	214.00	-60.00	42,469
1989	-227.54	243.00	7,092.13	1,229.00	47.22	1,406.75	-130.53	196.00	-80.00	43,582
1990	-228.08	241.41	6,961.59	1,191.00	46.91	1,397.50	-159.59	178.00	-100.00	44,927
1991	-228.74	239.45	6,802.00	1,173.00	46.53	1,386.19	-166.66	160.00	-100.00	46,522
1992	-229.44	237.41	6,635.34	1,173.00	46.13	1,374.38	-155.25	160.00	-100.00	48,244
1993	-230.10	235.51	6,480.10	1,173.00	45.76	1,363.37	-144.61	160.00	-100.00	49,967
1994	-230.72	233.74	6,335.48	1,173.00	45.42	1,353.12	-134.71	160.00	-100.00	51,688
1995	-231.30	232.09	6,200.77	1,173.00	45.10	1,343.58	-125.48	160.00	-100.00	53,404
1996	-231.84	230.56	6,075.29	1,173.00	44.80	1,334.69	-116.89	160.00	-100.00	55,112
1997	-232.35	229.12	5,958.40	1,173.00	44.52	1,326.40	-108.88	160.00	-100.00	56,810
1998	-232.82	227.79	5,849.52	1,173.00	44.26	1,318.68	-101.43	160.00	-100.00	58,496
1999	-233.27	226.55	5,748.10	1,173.00	44.02	1,311.50	-94.48	160.00	-100.00	60,168
2000	-233.69	225.39	5,653.62	1,173.00	43.79	1,304.80	-88.01	160.00	-100.00	61,824
2001	-234.08	224.32	5,565.61	1,173.00	43.58	1,298.56	-81.98	160.00	-100.00	63,462
2002	-234.44	223.31	5,483.63	1,173.00	43.39	1,292.75	-76.37	160.00	-100.00	65,081
2003	-234.79	222.38	5,407.27	1,173.00	43.21	1,287.34	-71.13	160.00	-100.00	66,680
2004	-235.11	221.23	5,336.15	1,173.00	42.98	1,280.70	-64.71	160.00	-100.00	68,258
2005	-235.40	219.69	5,271.43	1,173.00	42.69	1,271.78	-56.09	160.00	-100.00	69,793
2006	-235.66	218.35	5,215.34	1,173.00	42.43	1,264.04	-48.62	160.00	-100.00	71,249
2007	-235.88	217.19	5,166.73	1,173.00	42.20	1,257.34	-42.14	160.00	-100.00	72,631
2008	-236.08	216.19	5,124.59	1,173.00	42.01	1,251.53	-36.52	160.00	-100.00	73,945
2009	-236.24	215.32	5,088.06	1,173.00	41.84	1,246.49	-31.66	160.00	-100.00	75,199
2010	-236.39	214.57	5,056.41	1,173.00	41.69	1,242.13	-27.44	160.00	-100.00	76,397

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 160,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-23 - Case 1: Salton Sea Future Elevations and Salinities - Scenario 2
(conservation of 50,000 AF/year to a total of 200,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,323.00	47.68	1,420.57	-49.89	250.00	-40.00	40,902
1987	-226.95	244.78	7,237.31	1,265.00	47.56	1,417.04	-104.47	232.00	-80.00	41,691
1988	-227.37	243.50	7,132.83	1,207.00	47.31	1,409.63	-155.32	214.00	-120.00	42,818
1989	-228.02	241.60	6,977.51	1,149.00	46.94	1,398.62	-202.68	196.00	-160.00	44,298
1990	-228.86	239.12	6,774.83	1,091.00	46.46	1,384.26	-246.80	178.00	-200.00	46,166
1991	-229.90	236.10	6,528.03	1,073.00	45.87	1,366.77	-247.90	160.00	-200.00	48,474
1992	-230.95	233.06	6,280.13	1,073.00	45.28	1,349.20	-230.92	160.00	-200.00	50,973
1993	-231.95	230.24	6,049.22	1,073.00	44.73	1,332.84	-215.10	160.00	-200.00	53,526
1994	-232.89	227.60	5,834.11	1,073.00	44.22	1,317.59	-200.37	160.00	-200.00	56,130
1995	-233.78	225.15	5,633.74	1,073.00	43.75	1,303.39	-186.65	160.00	-200.00	58,779
1996	-234.61	222.87	5,447.10	1,073.00	43.30	1,290.17	-173.86	160.00	-200.00	61,468
1997	-235.39	219.74	5,273.43	1,073.00	42.69	1,272.05	-156.36	160.00	-200.00	64,189
1998	-236.11	216.01	5,117.08	1,073.00	41.97	1,250.49	-135.52	160.00	-200.00	66,869
1999	-236.74	212.78	4,981.55	1,073.00	41.34	1,231.81	-117.47	160.00	-200.00	69,427
2000	-237.30	209.99	4,864.09	1,073.00	40.80	1,215.61	-101.81	160.00	-200.00	71,859
2001	-237.79	207.56	4,762.27	1,073.00	40.33	1,201.58	-88.25	160.00	-200.00	74,167
2002	-238.21	205.46	4,674.02	1,073.00	39.92	1,189.41	-76.49	160.00	-200.00	76,354
2003	-238.59	203.64	4,597.54	1,073.00	39.57	1,178.86	-66.30	160.00	-200.00	78,424
2004	-238.91	202.06	4,531.24	1,073.00	39.26	1,169.72	-57.46	160.00	-200.00	80,383
2005	-239.20	200.69	4,473.77	1,073.00	38.99	1,161.80	-49.81	160.00	-200.00	82,237
2006	-239.45	199.51	4,423.97	1,073.00	38.76	1,154.93	-43.17	160.00	-200.00	83,994
2007	-239.67	198.48	4,380.80	1,073.00	38.56	1,148.98	-37.42	160.00	-200.00	85,661
2008	-239.85	197.59	4,343.38	1,073.00	38.39	1,143.82	-32.43	160.00	-200.00	87,245
2009	-240.02	196.81	4,310.94	1,073.00	38.24	1,139.35	-28.11	160.00	-200.00	88,755
2010	-240.16	196.14	4,282.83	1,073.00	38.11	1,135.48	-24.37	160.00	-200.00	90,196

[a] Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 160,000 AF over a 5-year period beginning in 1987.
[b] Direct rain = 0.1943 ft/year.
[c] Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-24 - Case 1: Salton Sea Future Elevations and Salinities - Scenario 3
(conservation of 50,000 AF/year to a total of 300,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,313.00	47.68	1,420.57	-59.89	250.00	-50.00	40,902
1987	-226.99	244.66	7,227.31	1,245.00	47.54	1,416.33	-123.79	232.00	-100.00	41,749
1988	-227.50	243.14	7,103.52	1,177.00	47.24	1,407.55	-183.31	214.00	-150.00	42,994
1989	-228.25	240.90	6,920.20	1,109.00	46.81	1,394.56	-238.76	196.00	-200.00	44,664
1990	-229.25	237.98	6,681.45	1,041.00	46.24	1,377.64	-290.40	178.00	-250.00	46,811
1991	-230.48	234.42	6,391.04	973.00	45.55	1,357.06	-338.51	160.00	-300.00	49,513
1992	-231.94	230.28	6,052.53	973.00	44.74	1,333.07	-315.33	160.00	-300.00	52,890
1993	-233.32	226.42	5,737.20	973.00	43.99	1,310.72	-293.73	160.00	-300.00	56,437
1994	-234.62	222.82	5,443.47	973.00	43.29	1,289.91	-273.61	160.00	-300.00	60,158
1995	-235.86	217.29	5,170.80	973.00	42.22	1,257.90	-242.68	160.00	-300.00	64,042
1996	-236.99	211.51	4,928.12	973.00	41.10	1,224.44	-210.35	160.00	-300.00	67,941
1997	-238.00	206.50	4,717.77	973.00	40.12	1,195.44	-182.32	160.00	-300.00	71,750
1998	-238.89	202.16	4,535.45	973.00	39.28	1,170.31	-158.03	160.00	-300.00	75,445
1999	-239.68	198.40	4,377.43	973.00	38.55	1,148.52	-136.97	160.00	-300.00	79,008
2000	-240.38	195.13	4,240.46	973.00	37.91	1,129.63	-118.72	160.00	-300.00	82,427
2001	-240.99	192.31	4,121.74	973.00	37.37	1,113.27	-102.90	160.00	-300.00	85,693
2002	-241.53	189.86	4,018.84	973.00	36.89	1,099.08	-89.19	160.00	-300.00	88,802
2003	-242.00	187.73	3,929.65	973.00	36.48	1,086.78	-77.31	160.00	-300.00	91,753
2004	-242.42	185.89	3,852.34	973.00	36.12	1,076.12	-67.01	160.00	-300.00	94,549
2005	-242.78	184.30	3,785.34	973.00	35.81	1,066.89	-58.08	160.00	-300.00	97,194
2006	-243.09	182.91	3,727.26	973.00	35.54	1,058.88	-50.34	160.00	-300.00	99,694
2007	-243.37	181.71	3,676.92	973.00	35.31	1,051.94	-43.63	160.00	-300.00	102,059
2008	-243.61	180.67	3,633.29	973.00	35.11	1,045.92	-37.82	160.00	-300.00	104,297
2009	-243.82	179.77	3,595.47	973.00	34.93	1,040.71	-32.78	160.00	-300.00	106,416
2010	-244.00	178.99	3,562.69	973.00	34.78	1,036.19	-28.41	160.00	-300.00	108,427

[a] Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 160,000 AF over a 5-year period beginning in 1987.
[b] Direct rain = 0.1943 ft/year.
[c] Evaporation = 5.789 ft/year.
Source: Parsons, 1985

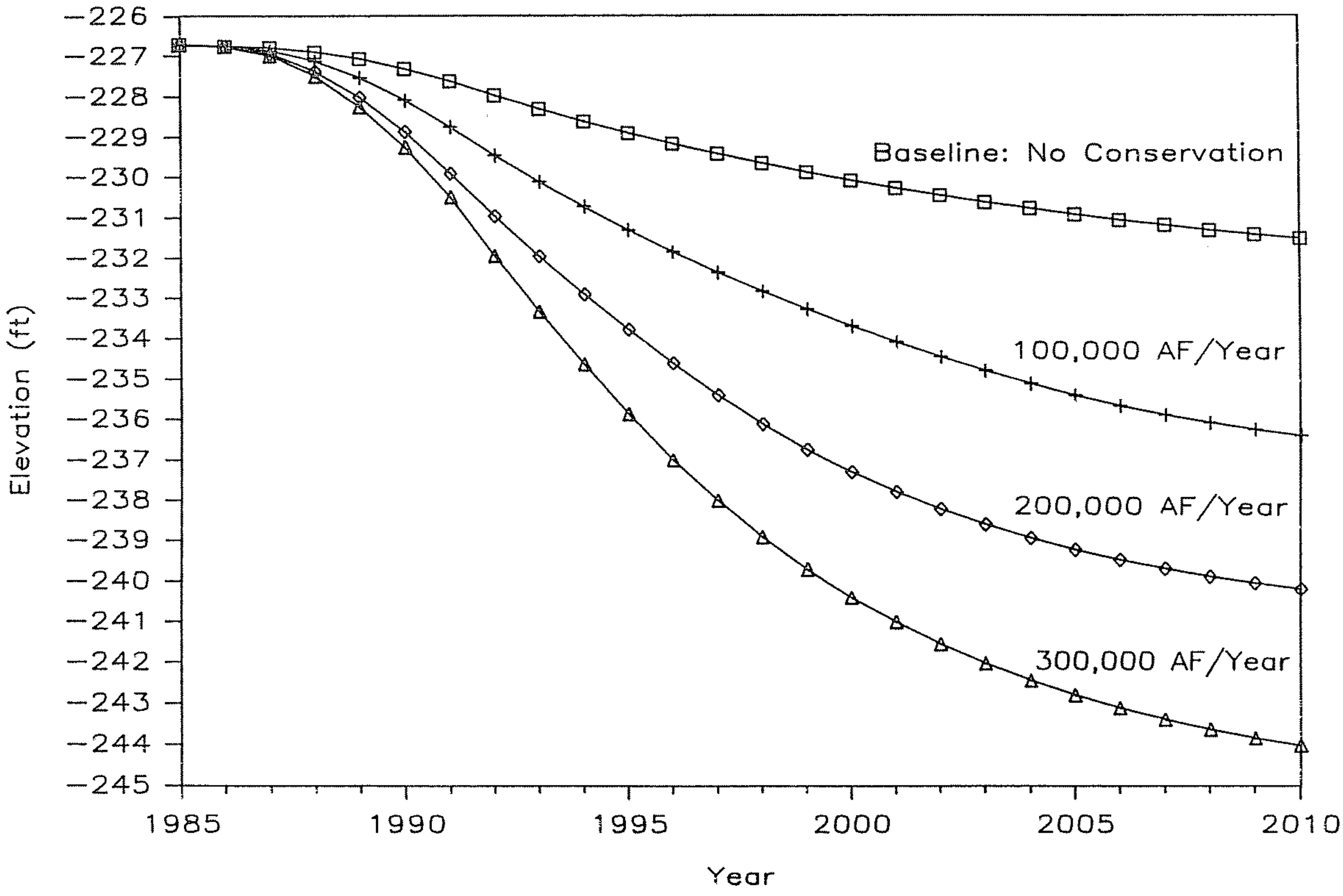


Figure 3-8 - Case 1: Salton Sea Projected Elevations (1985-2010)
(Parsons, 1985)

conservation effort to a very intensive conservation program with drastically reduced flows to the sea. All scenarios assume a gradually increasing quantity of water conserved, leveling off to a constant value after 5 or 10 years. All conservation efforts are assumed to begin in 1986.

Table 3-22 shows a moderate conservation effort. In this scenario, flows to the sea would be reduced by 20,000 AF/year to a limit of 100,000 AF/year as a result of IID's conservation. Under this scenario, the elevation would decrease to -236 ft and the salinity would increase to approximately 76,400 ppm by year 2010. This would be only a moderate increase from that projected by the baseline scenario.

Tables 3-23 and 3-24 show results of more aggressive water conservation programs. The second scenario assumes a reduction in flow to the Salton Sea over 5 years of 200,000 AF/year, while the third scenario assumes a reduction of 300,000 AF/year. Under scenarios 2 and 3, the elevation and salinity would be changed dramatically. By the year 2010, the salinity under the worst case (i.e., 300,000 AF/year reduced inflow) has increased to about 108,000 ppm.

The results presented in these tables are idealized for the purpose of demonstration. With very high salinities, the evaporation would be expected to change, as would other such parameters as the chemistry of the sea. Precipitation and other factors may come into play as significant mechanisms for removing salt. This analysis also assumes that the salt loading remains constant. However, this is unlikely because one of the probable methods of water conservation is desalination. Assuming that the waste brine is not disposed of in the sea, the salt loading would decrease.

2. Case 2. The conditions used to model the future elevations and salinity of the Salton Sea in Case 2 were the same as in Case 1, except for the inflow from Mexico. In Case 2, the inflow is stabilized at 200,000 AF/year compared to 160,000 AF/year in Case 1. Consequently, the elevations are higher and salinity lower in Case 2 because of the higher total inflow to the sea. Salt loading was maintained the same at 5 million tpy.

The results are shown in Tables 3-25 through 3-28 and the elevation changes are presented graphically in Figure 3-9. Under the baseline condition of no future conservation-induced reduction to the sea, the elevation would decrease to approximately -230 ft and the salinity would increase to approximately 58,500 ppm in year 2010. This would compare with -232 ft and 62,800 ppm in Case 1. Similar comparisons could be made for the conservation scenarios, which would result in reduced inflows of 100,000, 200,000, and 300,000 AF/year. In Case 2, with reduced inflows of 100,000 AF/year, the year 2010 elevation and salinity would be -235 ft and 70,800 ppm, respectively. With reduced inflows of 200,000 AF/year, the elevation and salinity would be -239 ft and 84,400 ppm, respectively. And with reduced inflow of 300,000 AF/year, the projected year 2010 elevation and salinities would be -242 ft and 100,300 ppm, respectively.

A comparison of the possible future scenarios is given in Table 3-29, which shows the approximate stable elevation and the year in which it would be reached under both Case 1 and Case 2. It is clear that, as more water is

Table 3-25 - Case 2: Salton Sea Future Elevations and Salinities (baseline - no conservation).

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,363.00	47.68	1,420.57	-9.89	250.00	0.00	40,902
1987	-226.78	245.27	7,277.31	1,353.00	47.66	1,419.87	-19.21	240.00	0.00	41,462
1988	-226.86	245.04	7,258.09	1,343.00	47.61	1,418.51	-27.90	230.00	0.00	42,079
1989	-226.98	244.69	7,230.19	1,333.00	47.54	1,416.53	-35.99	220.00	0.00	42,749
1990	-227.12	244.25	7,194.21	1,323.00	47.46	1,413.98	-43.52	210.00	0.00	43,474
1991	-227.30	243.72	7,150.68	1,313.00	47.35	1,410.90	-50.54	200.00	0.00	44,253
1992	-227.51	243.10	7,100.14	1,313.00	47.23	1,407.32	-47.08	200.00	0.00	45,086
1993	-227.70	242.53	7,053.06	1,313.00	47.12	1,403.98	-43.86	200.00	0.00	45,908
1994	-227.88	241.99	7,009.20	1,313.00	47.02	1,400.87	-40.85	200.00	0.00	46,720
1995	-228.05	241.49	6,968.35	1,313.00	46.92	1,397.98	-38.05	200.00	0.00	47,521
1996	-228.21	241.02	6,930.30	1,313.00	46.83	1,395.28	-35.45	200.00	0.00	48,313
1997	-228.36	240.59	6,894.85	1,313.00	46.75	1,392.77	-33.02	200.00	0.00	49,094
1998	-228.50	240.18	6,861.83	1,313.00	46.67	1,390.43	-30.76	200.00	0.00	49,866
1999	-228.62	239.81	6,831.07	1,313.00	46.59	1,388.25	-28.65	200.00	0.00	50,629
2000	-228.74	239.46	6,802.42	1,313.00	46.53	1,386.22	-26.69	200.00	0.00	51,383
2001	-228.85	239.13	6,775.73	1,313.00	46.46	1,384.32	-24.86	200.00	0.00	52,128
2002	-228.96	238.83	6,750.87	1,313.00	46.40	1,382.56	-23.16	200.00	0.00	52,864
2003	-229.06	238.54	6,727.71	1,313.00	46.35	1,380.92	-21.57	200.00	0.00	53,593
2004	-229.15	238.28	6,706.14	1,313.00	46.30	1,379.39	-20.10	200.00	0.00	54,314
2005	-229.23	238.03	6,686.04	1,313.00	46.25	1,377.97	-18.72	200.00	0.00	55,027
2006	-229.31	237.80	6,667.32	1,313.00	46.21	1,376.64	-17.44	200.00	0.00	55,733
2007	-229.38	237.59	6,649.89	1,313.00	46.16	1,375.41	-16.24	200.00	0.00	56,432
2008	-229.45	237.39	6,633.65	1,313.00	46.13	1,374.25	-15.13	200.00	0.00	57,124
2009	-229.51	237.21	6,618.52	1,313.00	46.09	1,373.18	-14.09	200.00	0.00	57,810
2010	-229.57	237.03	6,604.42	1,313.00	46.06	1,372.18	-13.13	200.00	0.00	58,490

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), and 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 200,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-26 - Case 2: Salton Sea Future Elevations and Salinities - Scenario 1
(conservation of 20,000 AF/year to a total of 100,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,343.00	47.68	1,420.57	-29.89	250.00	-20.00	40,902
1987	-226.87	245.03	7,257.31	1,313.00	47.61	1,418.45	-57.84	240.00	-40.00	41,577
1988	-227.10	244.32	7,199.46	1,283.00	47.47	1,414.35	-83.88	230.00	-60.00	42,421
1989	-227.45	243.29	7,115.58	1,253.00	47.27	1,408.41	-108.14	220.00	-80.00	43,438
1990	-227.89	241.97	7,007.44	1,223.00	47.01	1,400.75	-130.73	210.00	-100.00	44,633
1991	-228.43	240.37	6,876.71	1,213.00	46.70	1,391.48	-131.78	200.00	-100.00	46,016
1992	-228.98	238.75	6,744.93	1,213.00	46.39	1,382.14	-122.75	200.00	-100.00	47,460
1993	-229.50	237.25	6,622.18	1,213.00	46.10	1,373.44	-114.34	200.00	-100.00	48,895
1994	-229.98	235.85	6,507.84	1,213.00	45.83	1,365.34	-106.51	200.00	-100.00	50,319
1995	-230.44	234.55	6,401.32	1,213.00	45.57	1,357.79	-99.22	200.00	-100.00	51,731
1996	-230.86	233.33	6,302.10	1,213.00	45.34	1,350.76	-92.42	200.00	-100.00	53,129
1997	-231.26	232.20	6,209.68	1,213.00	45.12	1,344.21	-86.09	200.00	-100.00	54,511
1998	-231.63	231.15	6,123.59	1,213.00	44.91	1,338.11	-80.20	200.00	-100.00	55,878
1999	-231.98	230.16	6,043.39	1,213.00	44.72	1,332.42	-74.70	200.00	-100.00	57,228
2000	-232.30	229.25	5,968.69	1,213.00	44.54	1,327.13	-69.59	200.00	-100.00	58,560
2001	-232.61	228.40	5,899.10	1,213.00	44.38	1,322.20	-64.82	200.00	-100.00	59,874
2002	-232.89	227.60	5,834.28	1,213.00	44.22	1,317.60	-60.38	200.00	-100.00	61,170
2003	-233.16	226.87	5,773.90	1,213.00	44.08	1,313.33	-56.25	200.00	-100.00	62,446
2004	-233.40	226.18	5,717.65	1,213.00	43.95	1,309.34	-52.39	200.00	-100.00	63,703
2005	-233.64	225.54	5,665.26	1,213.00	43.82	1,305.63	-48.81	200.00	-100.00	64,942
2006	-233.85	224.94	5,616.46	1,213.00	43.71	1,302.17	-45.46	200.00	-100.00	66,160
2007	-234.05	224.38	5,570.99	1,213.00	43.60	1,298.95	-42.35	200.00	-100.00	67,360
2008	-234.24	223.86	5,528.64	1,213.00	43.50	1,295.94	-39.45	200.00	-100.00	68,541
2009	-234.42	223.38	5,489.20	1,213.00	43.40	1,293.15	-36.75	200.00	-100.00	69,704
2010	-234.58	222.93	5,452.45	1,213.00	43.32	1,290.54	-34.23	200.00	-100.00	70,848

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), and 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 200,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-27 - Case 2: Salton Sea Future Elevations and Salinities - Scenario 2 (conservation of 40,000 AF/year to a total of 200,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,323.00	47.68	1,420.57	-49.89	250.00	-40.00	40,902
1987	-226.95	244.78	7,237.31	1,273.00	47.56	1,417.04	-96.47	240.00	-80.00	41,691
1988	-227.34	243.60	7,140.83	1,223.00	47.33	1,410.20	-139.87	230.00	-120.00	42,770
1989	-227.92	241.89	7,000.96	1,173.00	47.00	1,400.29	-180.29	220.00	-160.00	44,149
1990	-228.67	239.68	6,820.68	1,123.00	46.57	1,387.51	-217.94	210.00	-200.00	45,855
1991	-229.58	237.01	6,602.74	1,113.00	46.05	1,372.06	-213.01	200.00	-200.00	47,926
1992	-230.48	234.40	6,389.72	1,113.00	45.54	1,356.97	-198.42	200.00	-200.00	50,099
1993	-231.34	231.98	6,191.30	1,113.00	45.07	1,342.91	-184.83	200.00	-200.00	52,298
1994	-232.14	229.71	6,006.47	1,113.00	44.63	1,329.81	-172.17	200.00	-200.00	54,519
1995	-232.89	227.61	5,834.29	1,113.00	44.22	1,317.61	-160.38	200.00	-200.00	56,759
1996	-233.60	225.64	5,673.91	1,113.00	43.84	1,306.24	-149.40	200.00	-200.00	59,011
1997	-234.26	223.81	5,524.51	1,113.00	43.49	1,295.65	-139.17	200.00	-200.00	61,272
1998	-234.89	222.11	5,385.35	1,113.00	43.16	1,285.79	-129.63	200.00	-200.00	63,538
1999	-235.47	219.32	5,256.00	1,113.00	42.61	1,269.65	-114.03	200.00	-200.00	65,801
2000	-236.00	216.60	5,141.96	1,113.00	42.09	1,253.93	-98.84	200.00	-200.00	67,976
2001	-236.45	214.25	5,043.13	1,113.00	41.63	1,240.30	-85.67	200.00	-200.00	70,037
2002	-236.86	212.21	4,957.46	1,113.00	41.23	1,228.49	-74.25	200.00	-200.00	71,989
2003	-237.21	210.44	4,883.20	1,113.00	40.89	1,218.25	-64.36	200.00	-200.00	73,836
2004	-237.51	208.91	4,818.84	1,113.00	40.59	1,209.38	-55.79	200.00	-200.00	75,585
2005	-237.78	207.58	4,763.05	1,113.00	40.33	1,201.69	-48.35	200.00	-200.00	77,243
2006	-238.02	206.43	4,714.70	1,113.00	40.11	1,195.02	-41.91	200.00	-200.00	78,815
2007	-238.22	205.43	4,672.79	1,113.00	39.92	1,189.24	-36.33	200.00	-200.00	80,308
2008	-238.40	204.57	4,636.47	1,113.00	39.75	1,184.23	-31.49	200.00	-200.00	81,730
2009	-238.55	203.82	4,604.98	1,113.00	39.60	1,179.89	-27.29	200.00	-200.00	83,087
2010	-238.68	203.17	4,577.69	1,113.00	39.48	1,176.13	-23.65	200.00	-200.00	84,386

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), and 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 200,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

Table 3-28 - Case 1: Salton Sea Future Elevations and Salinities - Scenario 3
(conservation of 50,000 AF/year to a total of 300,000 AF/year)

Year	Elev. (ft)	Area (acres)	Volume (1,000 AF)	Total Inflow[a] (1,000 AF)	Direct Rain[b] (1,000 AF)	Evapor.[c] (1,000 AF)	Storage Change (1,000 AF)	Mexico Inflow (1,000 AF)	Change Conser. (1,000 AF)	Salinity (ppm)
1985	-226.70	245.52	7,297.82	1,363.00	47.70	1,421.32	-10.62	250.00	0.00	40,338
1986	-226.74	245.39	7,287.20	1,313.00	47.68	1,420.57	-59.89	250.00	-50.00	40,902
1987	-226.99	244.66	7,227.31	1,253.00	47.54	1,416.33	-115.79	240.00	-100.00	41,749
1988	-227.46	243.24	7,111.52	1,193.00	47.26	1,408.12	-167.86	230.00	-150.00	42,946
1989	-228.16	241.19	6,943.66	1,133.00	46.86	1,396.23	-216.36	220.00	-200.00	44,514
1990	-229.06	238.54	6,727.29	1,073.00	46.35	1,380.89	-261.54	210.00	-250.00	46,492
1991	-230.16	235.34	6,465.75	1,013.00	45.73	1,362.36	-303.63	200.00	-300.00	48,941
1992	-231.46	231.62	6,162.12	1,013.00	45.00	1,340.84	-282.84	200.00	-300.00	51,949
1993	-232.69	228.16	5,879.28	1,013.00	44.33	1,320.79	-263.46	200.00	-300.00	55,074
1994	-233.86	224.93	5,615.82	1,013.00	43.70	1,302.12	-245.42	200.00	-300.00	58,312
1995	-234.95	221.93	5,370.40	1,013.00	43.12	1,284.73	-228.61	200.00	-300.00	61,661
1996	-235.99	216.63	5,143.04	1,013.00	42.09	1,254.07	-198.98	200.00	-300.00	65,102
1997	-236.92	211.89	4,944.05	1,013.00	41.17	1,226.64	-172.47	200.00	-300.00	68,466
1998	-237.74	207.78	4,771.58	1,013.00	40.37	1,202.86	-149.49	200.00	-300.00	71,711
1999	-238.47	204.22	4,622.10	1,013.00	39.68	1,182.25	-129.57	200.00	-300.00	74,826
2000	-239.11	201.14	4,492.53	1,013.00	39.08	1,164.39	-112.31	200.00	-300.00	77,802
2001	-239.67	198.46	4,380.22	1,013.00	38.56	1,148.90	-97.34	200.00	-300.00	80,636
2002	-240.16	196.14	4,282.88	1,013.00	38.11	1,135.48	-84.37	200.00	-300.00	83,327
2003	-240.59	194.14	4,198.51	1,013.00	37.72	1,123.85	-73.13	200.00	-300.00	85,878
2004	-240.97	192.39	4,125.38	1,013.00	37.38	1,113.77	-63.39	200.00	-300.00	88,291
2005	-241.30	190.88	4,061.99	1,013.00	37.09	1,105.03	-54.94	200.00	-300.00	90,574
2006	-241.59	189.58	4,007.05	1,013.00	36.83	1,097.45	-47.62	200.00	-300.00	92,733
2007	-241.84	188.44	3,959.43	1,013.00	36.61	1,090.89	-41.27	200.00	-300.00	94,777
2008	-242.06	187.46	3,918.16	1,013.00	36.42	1,085.20	-35.78	200.00	-300.00	96,714
2009	-242.25	186.61	3,882.38	1,013.00	36.26	1,080.27	-31.01	200.00	-300.00	98,552
2010	-242.42	185.87	3,851.37	1,013.00	36.11	1,075.99	-26.88	200.00	-300.00	100,300

[a]Baseline inflow = 810,000 AF (IID), 208,000 AF (Coachella), and 95,000 AF (other); Mexico inflow is 250,000 AF initially and decreases to 200,000 AF over a 5-year period beginning in 1987.
[b]Direct rain = 0.1943 ft/year.
[c]Evaporation = 5.789 ft/year.
Source: Parsons, 1985.

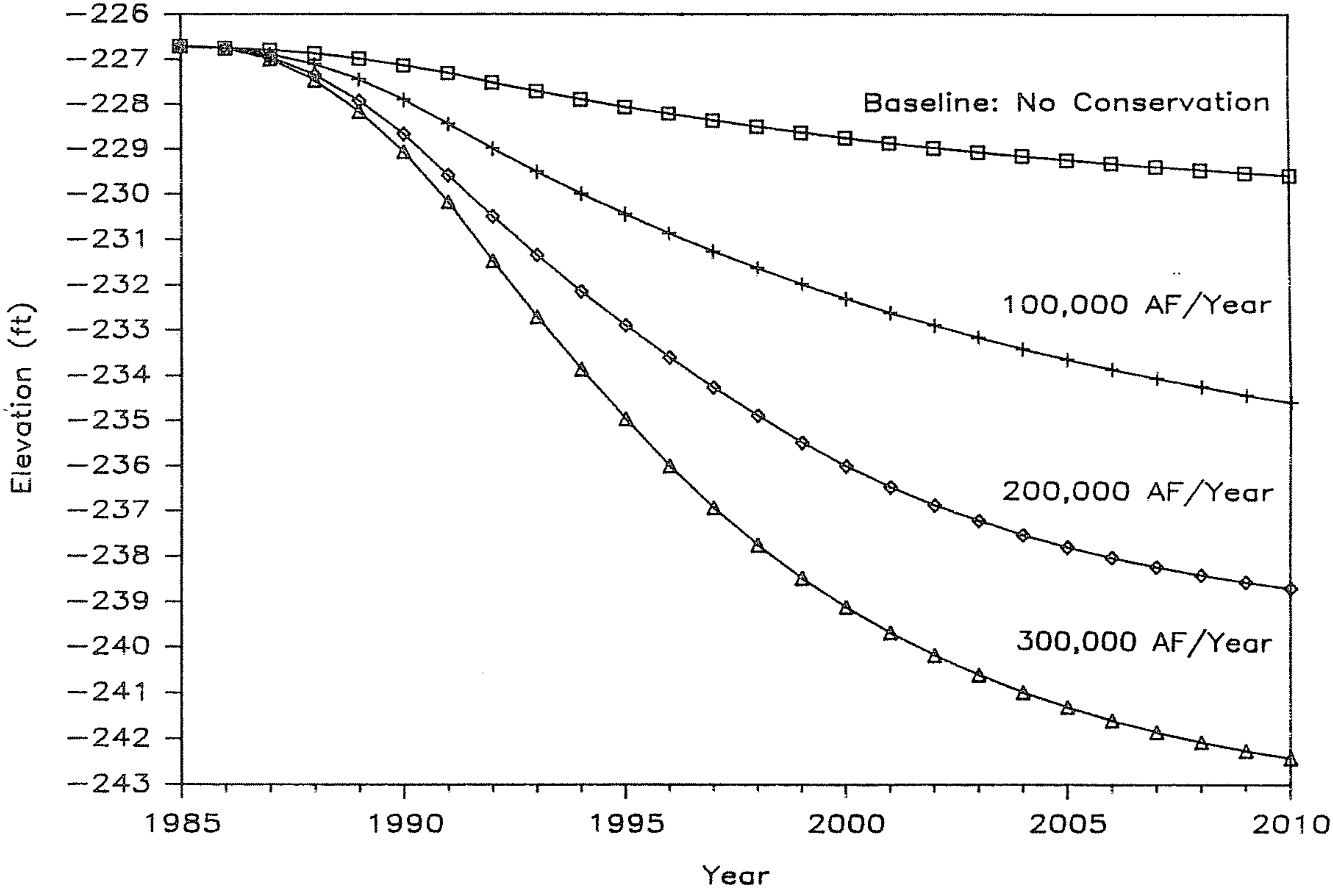


Figure 3-9 - Case 2: Salton Sea Projected Elevations (1985-2010)
(Parsons, 1985)

Table 3-29 - Comparison of the Effect of Conservation on Salton Sea Elevation: Case 1 vs. Case 2

Conservation Scenario (reduced inflow)	Case 1[a] Stabilizing Elevation (ft)	Case 1[a] Year[c]	Case 2[b] Stabilizing Elevation (ft)	Case 2[b] Year[c]
Baseline	-232	2050	-230	2047
100,000 AF/year	-237	2034	-236	2037
200,000 AF/year	-241	2033	-240	2033
300,000 AF/year	-245	2034	-245	2034

[a]Mexico inflow stabilized at 160,000 AF/year.
[b]Mexico inflow stabilized at 200,000 AF/year.
[c]Year of stabilization defined as year in which change in volume is less than 1,000 AF.
Source: Parsons, 1985.

conserved, resulting in reduced inflows to the sea, the elevation will ultimately be lower. A comparison of Case 1 with Case 2 shows slightly higher elevations under Case 2 as a result of higher inflows to the sea. However, this effect would decrease as the amount of conserved water increases. At 300,000 AF/year, the stabilizing elevation would be approximately the same, regardless of inflow from Mexico.

The increasing salinity of the sea has been recognized as a problem for some time. The analysis presented here assumes that no active measures are taken to help control salinity. However, control measures are possible, as discussed in the Federal-State Feasibility Report (U.S. Department of the Interior and the Resources Agency, State of California, 1974). These programs would be very expensive and would be feasible only if funded by omnibus state or federal agencies, but they provide potential ways of controlling the salinity of the sea. However, it should be noted that the lower the flows and the higher the salinity of the inflow to the sea, the more difficult it would become to effectively control the salinity.

The Salton Sea, as previously mentioned, shows an increase in salinity since 1955. In 1984, the salinity had increased to 40,353 ppm (IID, 1984). Because of the high evaporation rates and no outflow from the sea, the salinity of the sea is expected to continue to rise, regardless of conservation practices. Therefore, the Salton Sea is limited as a water resource. Although it now has significant beneficial use for fish, wildlife, and recreation, any future development for irrigation or municipal use would depend on desalination projects to reduce salt concentrations to suitable levels.

CHAPTER 4

DISTRICT BASELINE SYSTEM

The status of IID facilities and the method of system operation significantly affect the potential for water conservation. An inventory of these facilities and an assessment of existing system O&M procedures must precede, therefore, any attempt to define the baseline criteria for IID water loss reduction.

4.1. FACILITY INVENTORY

District facilities are organized in the following nine categories:

(1) Imperial Dam and desilting works
(2) All-American Canal
(3) Distribution canals
(4) Reservoirs
(5) Drains
(6) Pipe systems
(7) Metering and controls
(8) Yards and maintenance facilities
(9) Power facilities

4.1.1 IMPERIAL DAM AND DESILTING WORKS

The Imperial Dam, owned by the USBR, is located approximately 148 miles downstream from Parker Dam on the Colorado River and approximately 10 miles northeast of Yuma, Arizona. Dam construction was started in the early 1930s and was completed in 1938. The Imperial Dam is the principal diversion structure for the river flows apportioned to southern Arizona, the southern desert areas in California, and Mexico. Before release to California and portions of Arizona, river flows are passed through trash racks and three desilting basins to remove floating trash and up to 70,000 tpd of silt.

According to a 1947 agreement with the USBR, the District took over the O&M of the All-American Canal from Pilot Knob downstream, and in 1952 it assumed responsibility for the Canal headworks and desilting basins. In 1983, an additional agreement with the USBR became effective, by which the District assumed the O&M responsibility of the Imperial Dam, the California sluiceway, the Gila Gravity Main Canal headworks, the Senator Wash Dam and Reservoir (upstream), and the Laguna Dam (downstream), all USBR property. Operation of the All-American Canal and associated diversions and control structures had been previously transferred to the District according to agreements with USBR in 1947 and 1952. In 1983 and 1984, totals of 7.8 and 8.3 million AF, respectively, were diverted at the Imperial Dam into the All-American Canal for water usage downstream of the dam. A record of sediment removals at the Imperial Dam desilting basins, from 1961 through 1984, is shown on Table 4-1.

These records indicate high quantities of silt for the years of 1980 and 1983 because of extremely high flows in the river caused by spring runoff from snowmelts following unusually snowy winters.

Table 4-1 - Sediment Removed by Desilting Basins at Imperial Dam (1961 through 1984)

Year	Total Annual Sediment (tons)	High Month	Total (tons)	Low Month	Total (tons)
1961	196,553	July	58,635	December	144
1962	337,927	July	81,120	December	338
1963	515,033	July	100,802	December	551
1964	392,573	July	120,565	December	331
1965	433,468	August	143,109	January	439
1966	542,921	July	180,225	January	455
1967	318,777	August	92,033	December	259
1968	459,410	March	130,290	December	481
1969	467,052	April	98,337	December	264
1970	445,798	April	180,957	November	858
1971	441,146	April	122,157	January	1,088
1972	439,086	April	138,713	December	1,351
1973	481,774	April	181,326	February	1,169
1974	626,447	April	201,486	January	1,103
1975	470,161	April	132,456	November	994
1976	556,506	April	199,599	January	1,276
1977	530,026	July	150,466	December	1,651
1978	522,696	July	154,504	January	461
1979	646,766	July	201,383	January	176
1980	3,535,757[a]	July	1,331,953[a]	January	1,436
1981	455,671	August	145,520	October	75
1982	39,475	April	100,176	December	75
1983[b]	1,104,265[a]	May	389,891	March	1,406
1984	-[c]				

[a]Caused by extreme high river release.
[b]From July to December, the sediment pipes were submerged in high Colorado River water, and no samples were taken.
[c]No sample could be taken during 1984 because of continued high river releases.
Source: IID Water Report, 1984.

Because of Mexican treaty obligations and requirements for the Yuma Project and Wellton-Mohawk Project in Arizona, title to Imperial Dam and the associated facilities can never be transferred to the District. However, it is possible that the District may eventually acquire title to most of the All-American Canal.

4.1.2 ALL-AMERICAN CANAL

The All-American Canal was constructed by the USBR between 1934 and 1940. Since 1942, the entire water supply to the District has been received through this canal. The canal is unlined for its entire length and has a capacity of 15,155 ft^3/sec at the Imperial Dam headworks, where it runs southwesterly for approximately 82 miles to the junction with the Westside Main Canal.

The canal's designed capacity is reduced to 10,155 ft^3/sec below Pilot Knob Check because of the diversions at Siphon Drop and Pilot Knob. The capacity is reduced to 7,600 ft^3/sec below Drop No. 1; additional diversions further reduce the capacity to 2,655 ft^3/sec at the Westside Main Canal turnout. Siphon Drop supplies the Yuma Project. Pilot Knob supplies most of the Mexican treaty requirement, the remainder passes Imperial Dam into the Colorado River. The headworks of the Coachella Canal are at Drop No. 1.

In March 1947, the USBR transferred O&M responsibility of the All-American Canal to the District below the Pilot Knob check, and in May 1952 the District assumed O&M responsibility of the entire canal length, including the Pilot Knob check, spillway, and powerplant.

Although the USBR owns the All-American Canal in its entirety, including the drops, the District has constructed several hydroelectric powerplants at the drops. There is a hydroelectric powerplant at Pilot Knob, owned and operated by the District. The Coachella Canal diverts water to the Coachella Valley Water District from headworks located above Drop No. 1. At Drop No. 1, there is a hydroelectric powerplant owned and operated by the District. Downstream, the District owns and operates several additional hydroelectric powerplants. Operation of the hydroelectric powerplants causes fluctuations in water surface elevations above and below the powerplants. Although the fluctuations are small, they are sufficient to cause flow variations in all canals turning out from the All-American Canal. Improving flow regulation at the affected canal headgates is discussed in section 9.7. Damping-out of flow variations within canal systems occurs at and below the existing regulating reservoirs. The operation of existing and proposed new reservoirs is discussed in section 9.4.

It is possible that, at some future date, the District may acquire title to most of the length of the All-American Canal. The contract "... for Construction of Diversion Dam, Main Canal, and Appurtenant Structures and for Delivery of Water," dated December 1, 1932, between the District and the USBR, contains the following wording:

> "Title to remain with the United States. Article 22 ... the Secretary may, in his discretion, when repayments to the United States of all moneys advanced shall have been made, transfer the title to said main canal and appurtenant structures, except the

diversion dam and the main canal and appurtenant structures down to and including Syphon Drop, to the District or other agencies of the United States having a beneficial interest therein in proportion to their respective capital investments under such form or organization as may be acceptable to him."

At present, more than one-half of the federal money advanced for construction of the canal has been repaid. The ultimate holder of the title to the All-American Canal has not been decided at this time.

4.1.3 DISTRIBUTION CANALS

Water arriving at the District in the All-American Canal is distributed to the users through a series of main canals, supply canals, and laterals. The District's six main canals are described as follows:

(1) The East Highline Canal starts at the All-American Canal about 4 miles downstream of Drop No. 4 and serves all of the eastern sector of the District and portions of the central sector. The canal is unlined for its entire length of 45.09 miles and has an initial capacity of 2,700 ft^3/sec at its diversion from the All-American Canal. Portions of the central area of the IID are supplied from this canal through the Rositas Supply Canal and the Vail Supply Canal.

(2) The Central Main Canal starts at the All-American Canal just north of Calexico and serves most of the central portion of the IID. The canal is unlined for its entire length of 26.64 miles and has an initial capacity of 1,300 ft^3/sec at its turnout from the All-American Canal. Near the end of this canal, south of Brawley, flows are conveyed to the north-central area through the Rockwood Canal, which eventually joins the Vail Canal near the North End Dam, thereby interconnecting with the Vail Supply Canal coming from the East Highline Canal.

(3) The Westside Main Canal starts at the west end of the All-American Canal and serves the western portion of the IID. The canal is unlined for its entire length of 44.60 miles and has an initial capacity of 1,300 ft^3/sec at the All-American Canal. The major supply branches from this canal are the Fillaree Canal, the Thistle Canal, and the Trifolium Extension.

(4) The Briar/New Briar Canal is in the south-central portion of the valley and supplies several minor canals that originally received their water supplies directly from the All-American Canal. The canal is concrete-lined for its entire length of 5.21 miles and has a capacity of 320 ft^3/sec.

(5) The Rositas Canal is in the southeastern portion of the Valley and principally supplies the Rose and Redwood Canal systems. It is lined for approximately 7,200 ft of its total length of 11.14 miles, and has an initial capacity of approximately 300 ft^3/sec.

(6) The Vail Canal is in the north-central portion of the valley adjacent to the Salton Sea and serves the Vail system. It is lined for 4.59

miles of its total length of 17.85 miles and has an initial capacity of approximately 300 ft^3/sec.

Two areas at the south end of the valley receive water directly from the All-American Canal through relatively small canals and laterals. Some of these canals and laterals are partially lined.

The current status of canal lining, by operating division, is shown on Table 4-2, which is taken from the IID's 1984 Water Report.

The lining of sections of distribution canals and laterals began in 1954. From 1954 until 1984, canal lining was carried out on a cost-sharing basis with adjoining landowners. Under this program, over 850 miles of canals and laterals were lined in discontinuous stretches, based on landowner requests and their willingness to pay a share of the costs. At present, the District is proceeding with allocated funds, under full District responsibility, to line sections of canals and laterals. Highest benefit-cost linings are being installed first. Areas of particularly pervious soils and short, unlined sections between previously lined sections are considered as having highest benefit-cost ratios. The District indicates that 43.49 miles of canals and laterals were lined under the current program in 1984 (IID Water Report, 1984). The District projects an approximate additional 30 miles of lining to be installed in 1985.

4.1.4 RESERVOIRS

At present, the District operates four regulating reservoirs located at key points along the main canals. Singh Reservoir helps regulate the East Highline Canal and is located 1.5 miles south and 9 miles east of Calipatria at the Vail supply heading. Oscar Fudge Reservoir is located approximately 1.5 miles southwest of the terminal end of the Central Main Canal and Rockwood heading. Herman "Red" Sperber Reservoir is located at the end of the Rositas Supply Canal. To the west, the J. Melvin Sheldon Reservoir has been built at approximately the midpoint of the Westside Main Canal. Specific data on these reservoirs is presented in Table 4-3.

The District has scheduled construction of a fifth regulating reservoir on the Westside Main Canal at the head of the Trifolium Extension; however, construction has been temporarily deferred. The planned capacity is approximately 300 AF in an area of 30 acres. In addition, a sixth reservoir is in the planning stage, to be located near the head of the Niland Extension.

In its 1985 Water Conservation Plan, the District cites three ways in which regulating reservoirs can save water:

(1) Conservation of canal spills that historically occur at the reservoir location.

(2) Conservation of canal spills in the affected service area.

(3) Reduction of tailwater in the affected service areas.

Table 4-2 - Lateral Canal Mileage as of December 31, 1984
(by division)

	Total (miles)	Earth Section		Concrete-Lined		Pipelined	
		Miles	%	Miles	%	Miles	%
Holtville	291.01	66.37	22.81	224.28	77.07	0.36	0.12
El Centro-Calexico	227.65	111.34	48.91	115.81	50.87	0.50	0.22
Imperial	199.44	61.75	30.96	136.65	68.52	1.04	0.52
Brawley	241.91	107.61	44.48	128.36	53.06	5.94	2.46
Westmorland	196.28	50.28	25.62	146.00	74.38	0.00	0.00
Calipatria	288.90	180.90	62.62	107.05	37.95	0.95	0.32
Total	1,445.19	578.25	40.01	858.15	59.38	8.79	0.61

Source: IID Water Report, 1984.

Table 4-3 - Reservoir Data

Data	Reservoir			
	Singh	Sheldon	Fudge	Sperber
Date of completion	1/20/76	3/29/77	2/26/82	5/1/83
Capacity (AF)	323	476	300	470
Area (acre)	32	50	37.5	64.6
Maximum depth (ft)	11	10	10	9
Inlet/outlet flow capacity (ft^3/sec)	100	100	100	100 inlet 2 @ 100 outlet
Inlet control	Automatic hydraulic	Automatic hydraulic	Automatic hydraulic	Automatic hydraulic
Outlet control	Remote control	Remote control	Remote control	Remote control
Cost ($000)	482.5	598.8	1,140.4	1,115.3

Source: IID Water Conservation Plan, 1985.

The foregoing benefits result largely from the regulating reservoir's role in evening out the canal flow rates. There is a long in-channel flow time for water ordered by any particular farmer. The flow rate at the delivery point is affected by such unpredictable variables as fluctuations in water level of the All-American Canal caused by hydropower operations, fluctuations in flow velocity in the All-American Canal or a main canal caused by sustained along-canal winds, imperfect operation of headgates and canal checks, and difficulty in rapid adjustment of control structures to compensate for the above. Furthermore, on-farm operations are adversely affected by any on-farm variability in irrigation flow rate from that planned. The presence of regulating reservoirs in the system permits reregulation of flow rates to bring flow rates closer to those planned. The reservoirs also permit short-term changes in flow rates when possible to accommodate requests by farmers for increased or decreased delivery rates.

4.1.5 DRAINS

The District has constructed, maintains, and operates an extensive open drainage system. The drains are sized for farm-drainage flows but can and have been used to remove stormwater to the extent feasible. Because of the flatness of farmlands within the Imperial unit, coupled with the steepness of the nearby mountains, flash flooding from mountain rainstorms is occasionally experienced. On some occasions, the storm flows exceed the capacity of the drains; however, the IID has no plan to alter these drains for flood control purposes.

There are more than 1,451 miles of drains in the District that drain into the New River, the Alamo River, and the Salton Sea. Both the New River and the Alamo River are maintained by the District as integral parts of the drainage system. Three control drop structures have been installed in the New River, and 13 in the Alamo River, to prevent scour, bank caving, and flooding. Similarly, control structures are installed in steeper sections of drainage ditches.

Drains collect tailwater from farm fields, leach water from tile drains under farm fields, and operational discharges from canals and laterals. The drainage system is laid out to provide a farm drainage outlet for each quarter-section of 160 acres. Drains are generally parallel to irrigation canals and laterals. Wherever possible, District drains are deep enough to receive leach water discharges from farm tile systems. Therefore, drainage ditches are generally quite deep, considerably deeper than most irrigation canals and laterals. Farm tiling is necessary to remove deep percolation from farm fields and to prevent the groundwater table from rising to the root zone. In the District, groundwater in farmed areas is generally too saline for many of the sensitive crops grown.

Where the drainage ditches cannot be constructed deep enough to receive a farm's tile drain discharge, the District has constructed, maintained, and operated sumps and pumps. At some locations, the District has, in cooperation with landowners, pipelined drains because of the considerable space required by deep open ditches. The current status of drainage, by operating division, is shown in Table 4-4.

4.1.6 PIPE SYSTEMS

At present, the total length of pipe systems in the District is only 122.06 miles (versus a District total of 3,154.26 miles of canals and drains). In other words, the pipelined total is only 3.8% of the total mileage. A summary of the miles in earth sections, concrete-lined and pipelined, is given in Table 4-5.

4.1.7 METERING AND CONTROLS

In general, the existing water distribution system depends on unmetered manual control for almost all locations in the system, with remote electronic metering and control at certain key locations. This system has served adequately for many years to measure and regulate flows. The measurements have been accurate enough to account for water deliveries and to allow billings generally acceptable to water users. However, gradual improvements in the system are being made.

Table 4-4 - Drain Mileage as of December 31, 1984
(by division)

	Total (miles)	Earth Section		Concrete-Lined		Pipelined	
		Miles	%	Miles	%	Miles	%
Holtville	117.33	98.15	83.65	0.40	0.34	18.78	16.01
El Centro-Calexico	79.83	73.07	91.53	0.00	0.00	6.76	8.47
Imperial	70.36	65.12	92.55	0.00	0.00	5.24	7.45
Brawley	219.27	216.24	98.62	0.00	0.00	3.03	1.38
Westmorland	136.12	133.83	98.31	0.00	0.00	2.30	1.69
Calipatria	281.02	261.06	92.90	0.00	0.00	19.96	7.10
Total (division)	903.93	847.46	93.75	0.40	0.34	56.07	6.21
Drainage	496.51	452.62	91.16	0.00	0.00	43.89	8.84
All-American	51.64	37.51	72.64	0.00	0.00	14.13	27.36
Grand total	1,452.08	1,337.59	92.12	0.40	0.34	114.09	7.85

Source: IID Water Report, 1984.

Table 4-5 - Canal and Drain Mileage as of December 31, 1984

Conveyance System	Total	Earth Section	Concrete-Lined	Pipelined
All-American Canal - canals	82.17	79.57	2.60	0.00
All-American Canal - drains	51.64	37.51	0.00	14.13
Main canals	150.52[a]	141.58[a]	8.94	0.00
Lateral canals	1,445.19	578.25	858.15	8.79
Drains	1,400.44	1,300.08	1,300.08	99.96
Total	3,129.96[a]	2,136.99[a]	870.09	122.88

[a]Value from IID in August 1985, not from Water Report.
Source: IID Water Conservation Plan, 1985.

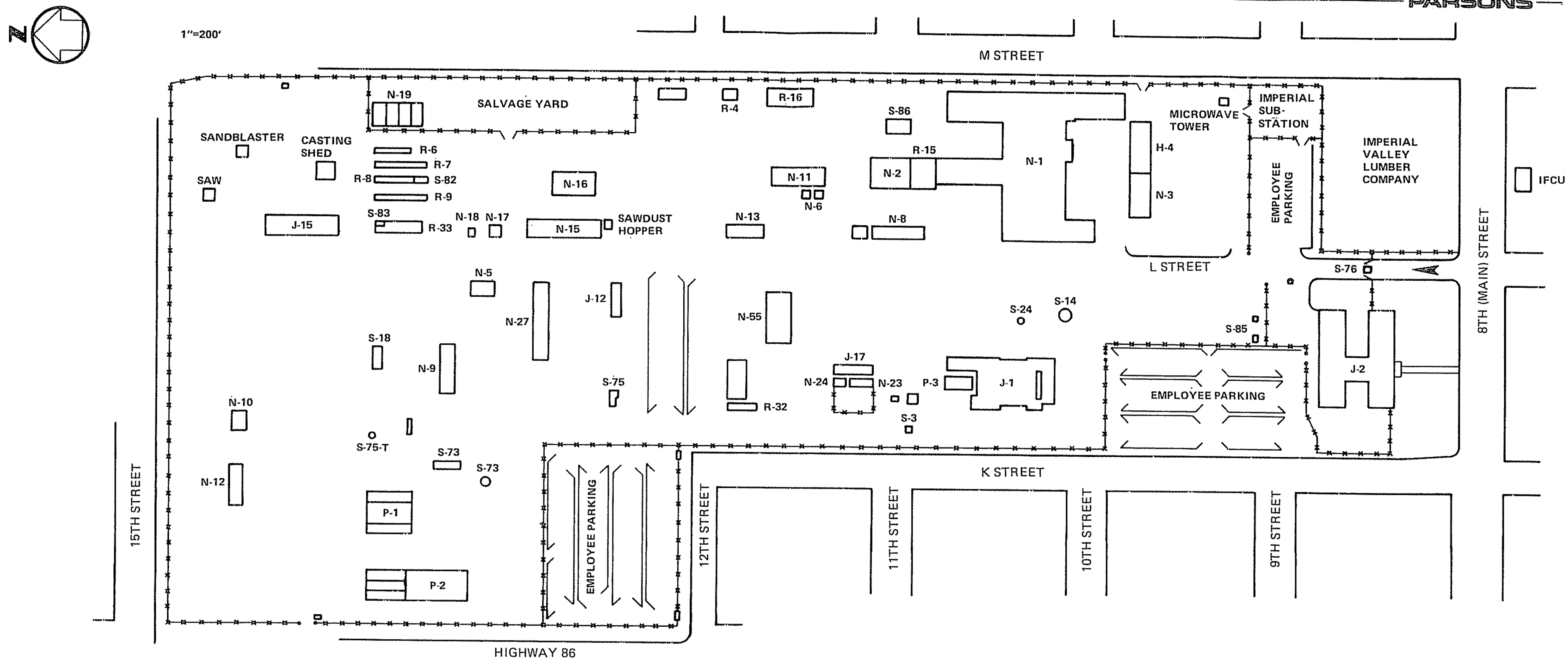
The District has installed remote electronic control devices at 22 major structures, including the All-American Canal and the four existing regulating reservoirs. The Water Control Section, under the direction of the Watermaster, operates the remote-control structures in the District. In case of power outages or other emergencies, standby generators are in place in many locations or the hydrographers operate these facilities manually. Flow variations resulting from hydropower operations at the drops in the All-American Canal and at the turnout to the East Highline Canal adversely affect existing remote control systems. Any further effort toward system automation must consider this factor.

All structures on distribution canals and laterals are operated manually by the hydrographers and zanjeros. Because many of the lateral and canal checks are old, wooden, and leaky, the flow rates passing these checks are not always those intended by the hydrographer. Furthermore, there is no means of correcting variations in water elevation upstream of these headgates, except by the hydrographer returning and manually resetting the headgates.

The canal checks and the farm deliveries are manually set by the zanjeros. The problems of accurate control of flow rates in distribution canals, laterals, and farm turnouts are discussed in section 9.6. Recording flow meters have been installed at a number of locations where no control structures exist at drop structures on main canals. Several experimental recording meters have been installed with broad-crested weirs in lined canals.

4.1.8 YARDS AND MAINTENANCE FACILITIES

The District owns and operates a large maintenance yard at its Operating Headquarters in Imperial and smaller maintenance yards at the five operating divisions of the Water Department and two All-American Canal O&M division



LEGEND

H-4 - Metal electrical and air-conditioning shop
J-1 - Plaster and metal roof (main office building)
J-2 - Cement-block and red-tile roof - supporting office building
J-12 - Meta! and wood transportation office
J-15 - Metal and concrete - Imperial Division office and shops
J-17 - Parsons wood and metal mobile office
N-1 - Metal and wood mechanical shops, store, and offices
N-2 - Metal and wood frame (power warehouse)
N-3 - Metal body and paint shops
N-5 - Metal and wood building (steel benders' shop)
N-6 - Metal storage containers
N-8 - Metal (new stores building)
N-9 - Metal building (sump pump storage and repair)
N-10 - Metal and wood old paint shed (miscellaneous storage)
N-11 - Metal and wood storage buildings
N-12 - Metal and concrete-covered dock (chemical and miscellaneous storage)
N-13 - Wood and metal siding (cement warehouse)
N-15 - Metal and wood buildings (ground office and shops)
N-16 - Wood arbor (concrete mixing and forming area)
N-18 - Wood and plaster plumbers shop
N-17 - Wood and plaster building (air-conditioning and fire-extinguisher shops)
N-19 - Marine cargo containers (records storage)
N-23 - Metal and wood water engine storage
N-24 - Metal and wood water control storage
N-27 - Open metal roof (chemical storage)
N-55 - Metal automotive service buildings
P-1 - Metal and concrete power dock (radio, meter, and relay shops)
P-3 - Metal and wood mobile building (power engineering additional office)
R-4 - Scrap metal yard
R-6 - Miscellaneous dock storage
R-7 - Dock storage
R-8 - Dock storage
R-9 - Wood
R-15 - Wood dock
R-16 - Wood solvent and chemical docks
R-32 - Wood loading docks
R-33 - Wood dock
S-3 - Wood and plaster pumphouse
S-14 - Wood pergola
S-24 - Flagpole
S-73 - Wood dock
Metal tank (transformer oil tank)
S-75 - Metal and wood icehouse
S-75-T - Metal tank
S-82 - Dock storage
S-83 - Metal and wood drainage shop (Water Department)
S-85 - Standby power plant for water control
S-86 - Steam equipment rack

Figure 4-1 - IID Headquarters Yard
Imperial, California

4.2 CURRENT OPERATIONS AND MAINTENANCE

The O&M of District facilities and on-farm activities are both extremely important in determining water conservation or losses. These aspects of the overall system, as well as the auxiliary subject of Public Relations, are examined in this section. The discussion of public relations is included because of the importance of keeping the public informed on IID actions, which are considered vital to continued economic health by many constituents.

4.2.1 TRANSMISSION AND DISTRIBUTION OPERATIONS

Water for the District is supplied entirely by the Colorado River. Because of the extensive travel time involved in delivering water from storage on the Colorado River to the District, the District must order daily increments of water on a weekly basis well in advance of receiving actual water orders from its users. It takes 5 days from the time water is released from Hoover Dam before it reaches Imperial Dam, which is a diversion dam with negligible storage. Except for a small diversion and storage facility at Senator Wash, deliveries must be regulated upstream at Parker Dam, a 2-1/2-day water travel time above Imperial Dam. Thus, any adjustment to a diversion at Imperial Dam must be made 72 hours in advance.

The system is complex, with over 150 miles of main canals and nearly 1,500 miles of laterals. The system operation is guided by rules and regulations that set forth the basic criteria for scheduling and delivering water. There is, however, great flexibility within these guidelines for operating the District. Much of this flexibility is in the physical capacity of the system, but the dedication and long experience of the District personnel in managing this complex system and adjusting to specific conditions is the key to the successful operation.

The following procedures govern scheduling and delivery of water in the Imperial Irrigation District.

A. Water Scheduling

1. User Water Orders. The water scheduling process begins with the individual signed order that is submitted by the water user to the division office or the zanjero in charge of the delivery. Orders can be placed for delivery not less than 1 nor more than 3 days in advance, on any day between 8:00 a.m. and 5:00 p.m., and they may be placed by phone on weekends and holidays. Orders received before noon may be for water delivery the following day. Orders placed after 12 noon are considered to be received the following day and effective the second following day. Each order pertains to only one account or delivery location. A landowner must submit one order for each delivery. Deliveries normally serve a maximum of 160 acres.

The District is required to begin delivery of the water ordered within the 3-day period starting with the day for which the water is ordered unless this is impossible because the delivery lateral is too small. Before an order can be delivered, it must be confirmed or verified by the Division. The following verification procedure is used to notify the user of the date on which delivery is to start:

(1) The user designates a telephone number where he can be contacted between the hours of 3:00 p.m. and 5:00 p.m.

(2) The user makes arrangements to call the District between 3:00 p.m. and 5:00 p.m.

(3) If steps 1 and 2 are not possible, the District and the user may make other arrangements as long as verification takes place between the hours of 3:00 p.m. and 5:00 p.m.

(4) If the water user desires, he may order on the basis that delivery will be accepted at any date within the 3-day period mentioned previously, without further verification.

With the exception of step 4, above, no irrigation run will begin until verification has taken place.

2. Scheduling by Division. As the individual water orders are received, the division water coordinators log each order for the following day by lateral and individual zanjero run, listing the account number, the amount of order, and how many days the order is to run on the Division Water Order Register. By 12 noon, the water coordinators know what orders need to be satisfied for the following day and what the flow requirement will be for each canal.

When flows exceed the lateral canal capacity, certain orders can be delayed by the water coordinators within the 3-day limit described above. Highest priority for service goes to those orders already running. The next group scheduled is those that have been delayed or "carried over" from the previous day's scheduling with the longest carryover receiving the higher priority. Priority for the other orders not on carryover is based on the time that the order was received. It should be noted that, other than for running orders or for orders that must be delivered to stay within the 3-day limit, the priority system described above may be altered at the discretion of the water coordinators.

The flow required in each canal for the following day is then recorded on the division's Daily Water Distribution Work Sheet and compared with the estimated order for that canal. The estimated order is based on total water estimated for each division by the Water Control Section and distributed among the division's lateral canals based on the current use pattern.

Total orders for the division are determined and compared with the amount estimated by Water Control. The Division Water Coordinators then call Water Control to verify the estimated order or request a change. Water Control, after analyzing similar data from all the division in light of current capabilities of the system, will notify each division of its revised allotment. The division then allocates the revised allotment among the various canals and enters the revised orders on the Daily Water Distribution Work Sheet. The water coordinators then make any final adjustment to individual deliveries on each zanjero run. With the following day's delivery now set, the water coordinators estimate the orders for the second and third following days, based on running orders and carryovers, and summarize the data for the entire division. The data is then phoned in to the Water Control Section where it is entered on their Daily Water Allotment sheet.

3. Daily Scheduling by the Water Control Section. The Water Control Section is responsible for allocating the next day's water supply among the various divisions. On a daily basis, Water Control performs the same function as the division water clerks but on a Districtwide basis. These operations are carried out at the Imperial Irrigation District Headquarters.

Water Control begins by allocating the water scheduled to arrive for the following day, less 300 ft^3/sec reserved for carryover orders, among the various divisions based on each division's use pattern and estimates of flow submitted on previous days. This data is entered on the Daily Water Allotment Sheet.

Each division is asked to "line up" on or attempt to schedule their water orders to meet this supply. As discussed in the previous section, after determining their water orders, the various divisions will call the dispatcher at Water Control to request revised allotments. Water Control analyzes these requests in view of system capabilities and determines how the 300 ft^3/sec reserved for carryover should be allocated among the divisions. The dispatcher then notifies each division of its revised allotment for the next day. Each division then prepares its adjusted schedules for the next day and estimates for the 2 days following. This information is called back to Water Control and logged on the Daily Water Allotment Sheet for use in scheduling the following day's deliveries and determining allotments for subsequent days. These Daily Water Allotment Sheets are also used in the process of scheduling releases from Imperial Dam explained in the following subsection.

4. Scheduling Diversions at Imperial Dam. The scheduling of diversions at Imperial Dam has two components: one involves determining the weekly order or "Master Schedule"; the other is modifying that Master Schedule on a daily basis.

On Wednesday of each week, the District orders its diversions from Imperial Dam for each day, Monday through Sunday, of the following week. This order becomes the Master Schedule for that week. Daily adjustments can be made to this Master Schedule assuming that notice is given 72 hours prior to the time Imperial Dam diversions are to begin for the day being revised. Restrictions placed on IID for making adjustments to its Master Schedule for a particular day are minimal.

The daily modifications are based on three considerations, with the main component being the Daily Water Allotment Sheets. These allotment sheets indicate the current trend of water orders up to the day being adjusted. The Watermaster then considers the day of the week (weekends generally require less water) and the current and projected weather conditions before deciding on any final adjustment to make in the daily water order.

The weekly order, or Master Schedule, also relies heavily on the Daily Water Allotment Sheets to set out the recent weekly trends in water orders. Weather is also considered but in a more general fashion (10- to 12-day forecast instead of a 2- or 3-day forecast). The Watermaster analyzes the seasonal crop demands or the irrigation cycle. The seasonal crop demands are based on time of year, cropping pattern, and status of the various crops (i.e., which crops are being planted, cultivated, or harvested at that time). The irrigation cycle, or seasonal crop demand, is also monitored by annual charts showing weekly fluctuations of water orders over the last 2 or 3 years. These charts allow comparison of the current weekly order to the order made the previous 2 years at the same time of year. This creates a historical as well as seasonal perspective for determining the weekly order. Finally, the Watermaster estimates what the conveyance losses will be in the system for the amount of water required. After considering all of the data, the Master Schedule is prepared and called into Imperial Dam.

B. Water Delivery

The Daily Water Allotment Sheet (from Water Control) and the division's Daily Water Distribution Work Sheets and Water Order Registers provide the framework for daily deliveries throughout the District. The Water Control Section hydrographers, under the direction of the District Watermaster, are responsible for delivering water into the main and lateral canal systems to meet the required flows to the various divisions. The zanjeros are responsible for making the deliveries from laterals to each individual farm headgate in accordance with the Water Order Register prepared for each lateral system zanjero run. The District currently employs about 140 hydrographers and zanjeros.

With the exception of a few deliveries made by the hydrographers to farm headgates on the main canals, the zanjeros make the deliveries to the farmers. Each zanjero operates a number of lateral canals that are known as zanjero runs.

Farm deliveries are made through a standard gated delivery structure. Flow rate is determined by setting the gate opening in relation to the difference in water elevation upstream and downstream of the gate. Rating curves have been developed so that the zanjero can set the proper gate opening to achieve the ordered head.

At the start of each daily run, the zanjero sets the headgates for the appropriate flows. He returns later in the day to adjust each headgate to maintain the ordered flow.

The zanjero is required to leave a printed notice of water delivered at the place of measurement every day water is run. Information on this notice includes the date and time of day the run began, the amount ordered, the gate opening, for whom the water is turned on, and the zanjero's signature. On subsequent days during a run, any change in amount ordered, and therefore a gate opening change, will be noted and signed off by the zanjero. Water charges are made daily for the amount delivered during each 24-hour period.

1. Delivery Requirements. Restrictions that must be met before deliveries will be made include:

(1) Water cannot be delivered unless ordered by the landowner or his authorized agent.

(2) Delivery can be refused if the user's ditch is not in a condition to carry the water.

(3) Deliveries are made in 24-hour periods or multiples thereof with adjustments as outlined in the following subsection.

(4) Water cannot be delivered to a consumer while there is a delinquent bill outstanding on any of the specific consumer accounts.

(5) The zanjero can reduce the water delivery to an amount he judges feasible if the amount ordered would exceed the capacity of the farmer's ditch. Water charges are adjusted to water actually delivered.

Penalties exist for users who do not stay within these limitations.

2. Operation Flexibility. In general, the two previous subsections set out the major components of the rules and regulations and the 21-Point Water Conservation Plan as they affect water orders and deliveries. These guidelines control operating deliveries. However, the District attempts to be flexible within these guidelines. For the most part, the zanjero and his supervisors play the key role in this added flexibility. For example, all deliveries are to be made in 24-hour periods, yet in the case of finish heads (see item 5 of Delivery Flexibility, below) a user may need only 2 more hours to finish an irrigation. If the zanjero can work it into the system, possibly by delaying another user's order by 2 hours, he will schedule that and the user will be billed for the extra 2 hours. This adjustment can be made because the zanjero can communicate directly with the affected users and knows the individual needs of users on his run.

3. Delivery Flexibility. The standard water order is for a certain flow in cubic feet per second (ordered as "feet") delivered in multiple periods of 24 hours at a particular headgate. The farmer, however, can revise his order within certain guidelines (i.e., without incurring a penalty) as set out in detail in the rules and regulations and the 21-Point Water Conservation Program (see Appendix F). These guidelines include:

(1) The user can make any change that he desires for the last day of his run as long as he notifies the District before 3:00 p.m. of the preceding day.

(2) The user can request that his order be adjusted up to 2 ft any day of his run as long as he notifies the zanjero before he begins his daily run. The zanjero must also get approval before this change can be made, and the change must be physically feasible.

(3) During the last day of his run, the water user can adjust the last 12 hours of his run up to 50% or 5 ft, whichever is less, as long as the District is notified before 3:00 p.m. on that day.

(4) If physically feasible, a user can change his water order from one gate to another on the same canal at any time as long as the switch is coordinated with the zanjero. The zanjero needs to be sure that the new gate is set properly and that the proper accounts are credited correctly.

(5) A user can extend his order an additional day (finish head) if done prior to 3:00 p.m. of the last day of his original order.

4.2.2 DRAINAGE SYSTEM

The District operates and maintains 1,451 miles of surface drains. Individual landowners have installed about 30,000 miles of tile drains and thousands of tailwater structures. Surface drains are used to collect surface flows from the fields (tailwater), tile drain discharges, and operational discharges from the canals and laterals. Most of these drains discharge their return flows into the Alamo or New Rivers, which then empty into the Salton Sea. Of the surface drains, 34 discharge 80,000 AF to 120,000 AF/year directly into the Salton Sea.

The tile drains are located in the fields and are buried at depths ranging from 6 to 10 ft (usually 6 ft). The tile drains are used to draw off the excess water derived from percolated surface flows in order to prevent the water table from encroaching into the root zone. Most of these drains are constructed of perforated plastic pipes in gravel envelopes and are connected to 8-in. to 12-in. collector pipes. Most of these drains discharge directly into surface drains; a few discharge directly into the Alamo and New Rivers. Tile drains have been installed on about 427,000 acres of farmland.

Surface flows that run off the ends of the fields are referred to as tailwater. Tailwater flows are collected by tailwater structures and, in most cases, are discharged into surface drains through pipes.

The drainage system provides a drainage outlet for each 160-acre parcel of land serviced by the District. The open channels and gravity-flow pipelines flow unattended. However, over 500 leachate sumps and pumps have been constructed and are maintained and operated by the District. The sumps and pumps are required wherever drain channels cannot be maintained deep enough to provide a gravity outlet for the farm tile.

Maintenance of the many open-channel drains, pipeline drains, and sump-pump systems requires a major yearly commitment of labor and equipment each year. Specific items of work include removal of silt deposits, weed control and removal, repair and replacement of drainage structures and sump pumps, and grading of drainage canal banks. Other drainage operations include design and construction of drainage structures, logging of soil profiles, seepage studies, and other studies and design of elements of the drainage system.

4.2.3 MAINTENANCE

The District's facilities and equipment are maintained by the District's staff; the work is divided among the departments (Table 4-6).

Table 4-6 - Assignment of IID Maintenance Responsibilities

Maintenance Category	Responsibility
Imperial Dam and All-American Canal	All-American Division Superintendents
Irrigation system (as well as new construction)	General Superintendent of Irrigation and Drainage and superintendents of the six Divisions
Drainage	Construction General Superintendent at IID Headquarters
Power Department	Construction and Maintenance General Superintendent at IID Headquarters
Buildings, grounds, and all operations mechanical equipment (from cars to draglines)	Operating Services Department at IID Headquarters
Office equipment	Office Services Supervisor at IID Headquarters

Source: IID, 1984.

4.2.4 DISTRICT STAFF

The operation of the District requires a large staff, over 900 persons, as shown in Table 4-7 from the District.

The personnel of the Water Department and numerous members of other supporting Departments are directly concerned with water conservation, a total of more than 400 people. This staff is totally committed to current activities.

4.2.5 ON-FARM OPERATIONAL PERSONNEL

On-farm water distribution operation and control are performed by the farm owner (or his irrigator), who is responsible for ensuring that irrigation water is evenly distributed to all sections of the field. Important on-farm decisions such as determining the quantity of water required for each irrigation and scheduling irrigation are generally performed by the farm owner. On large farms, a farm owner may hire a foreman or farm manager to make these decisions. On small farms, the farm owner is often both the irrigator and the scheduler. In the Imperial Valley, there is approximately one irrigator for every 1,000 acres of productive farmland. Additional irrigators

Table 4-7 - 1985 IID Staffing Table (recap)

Department	1984 Staff	1985 Authorized
Directors	5	5
General Managers	28	31
Finance and Accounting	63	63
Personnel	9	10
Operations Services	101	105
Power	313	318
Water	402	409
Total District Staffing	921	941

Source: IID 1985 Staffing Tables, December 1984.

may be required temporarily during initial irrigations when water distribution is most critical for seed germination or when mechanical equipment for water distribution is installed.

Throughout each 24-hour period, the irrigator performs numerous water distribution duties. The irrigator is responsible for operating and maintaining water flow in all on-farm distribution features, including lead and tailwater ditches, holding basins (tanks), field siphons, ditch slide-type gates, delivery pipes, mechanical irrigation equipment, and other appurtenant structures. Maintaining a constant water flow involves adjusting slide-type gates and pipe orifices. Removing moss, aquatic weeds, and debris in ditches and holding basins is required to prevent clogging the delivery pipes and tubes, which may result in an uneven water distribution in the field if unchecked. The irrigator is also responsible for ensuring that applied water is distributed evenly to each plant. Several innovative tools presently being used by Imperial Valley farmers such as facets, C-taps, screens, and mechanical moss removers are available to the irrigator to aid in the efficient use of applied irrigation water.

It must be noted that the irrigator represents the single most important factor in determining the effectiveness of on-farm water conservation program implementation. The extent and duration of tailwater runoff and deep percolation water losses from the farm field are determined largely by the irrigator. Thus, the irrigator's water distribution techniques and practices determine to a large degree the efficiency of water applied to the farm fields.

4.2.6 PUBLIC RELATIONS

The IID currently maintains a Public Information and Community Services section that reports directly to the General Manager. The section is tasked with supplying information about all District activities to the news media and the general public, as well as keeping the District informed about media coverage of the IID. The section is staffed by a Public Information and Community Services Director, an audiovisual specialist, and an education specialist, with clerical support. There is no dedicated person assigned to the water conservation and transfer program.

A. IID Staff

The IID Public Information and Community Services Section currently works with the news media in the Imperial Valley and, when needed, with media outside of the valley on issues of relevance to the District. The section has an excellent relationship with valley media, and it has good relationships with those media representatives outside of the valley with whom it has dealt. However, its contacts with the media outside of the valley are, by definition, more limited. The section also maintains an excellent program of community relations that includes frequent appearances before the Farm Bureau and other groups in the Valley.

The section maintains its own audiovisual department and is expanding its video capabilities, but it does not yet have the capability to produce sophisticated printed materials or broadcast-quality videos to support the water conservation and transfer program.

B. Consultant Support

Parsons has a senior public relations specialist assigned to the IID project who will report directly to the Program Director and use the resources of the Corporate Relations Department of The Parsons Corporation. The primary task of the public relations specialist is to assist the IID in formulating and implementing community, media, and legislative relations programs in order to explain and develop support for the IID's water conservation program.

The following key tasks have been identified as those that must be accomplished to implement the program:

(1) Imperial Valley Community Relations

The IID will be assisted in its efforts to inform and educate Imperial Valley growers, ranchers, and other residents about the advantages of a water conservation program. The community relations program will accomplish the following primary tasks:

(a) Identify authorized spokespersons for the water conservation and transfer program.

(b) Develop appropriate contacts with and supply factual information to the news media in the Imperial Valley and adjacent areas.

(c) Establish a process for the approval of materials made available to the news media and general public.

(d) Identify key groups, organizations, associations, and individuals within the Imperial Valley who are critical about the general acceptance of the water conservation and transfer program.

(e) Assist the IID in developing effective presentations that can be delivered jointly to concerned groups and individuals.

(f) Assist the IID in developing appropriate support materials for presentation or media usage.

(2) <u>Media Relations</u>

The IID will be assisted in providing people outside of the Imperial Valley with accurate information about the water conservation and transfer program. The program will accomplish the following primary tasks:

(a) Identify authorized spokespersons for the program.

(b) Supply the IID with approved news and background information to appropriate media outside the Imperial Valley.

(c) Supply the IID's information office with copies of all materials issued about the water conservation and transfer program.

(d) Assist the IID in obtaining news clippings, copies of broadcast reports, etc., concerned with water conservation and transfer programs.

(e) Arrange tours of the IID for selected members of the media.

(3) <u>Legislative Relations</u>

Parsons public relations specialist will assist the IID in developing and maintaining a legislative climate that favors the conservation and transfer of water. The program will accomplish the following primary tasks:

(a) Identify key legislators and officials concerned with the water conservation issue.

(b) Supply appropriate legislators and officials with IID-approved news and background information on the water conservation and transfer program.

(c) Arrange for tours of the IID by key legislators and officials.

(d) Assist the IID in preparing and/or delivering testimony to appropriate legislative or government bodies.

(4) Public Relations Plan

Parsons public relations specialist will assist the IID in preparing a plan to further public awareness, understanding, and acceptance of the IID Water Conservation Program.

4.3 BASELINE SYSTEM: WATER CONSERVED CRITERIA

The efforts of the District to conserve water over the past years have been effective. This section discusses the amount of water already conserved to define an order of magnitude value of this quantity and estimates the potential for further improvement as a baseline for additional analysis.

4.3.1 DELIVERY SYSTEM

Tables 4-8 and 4-9 show the increasing efficiency of the District's operation in recent years, commensurate with the District's program of canal lining and other water conservation measures. The data in Table 4-10 summarizes Tables 4-8 and 4-9.

Table 4-8 - Efficiency of Water Conveyance and On-Farm Irrigation (1977-1980)

Item	Representative Values
Diversions below Drop No. 1	2,734,000 AF
Delivered to farms	2,496,500 total AF
Conveyance system efficiency	91% (item 2/item 1)
On-farm consumptive use	1,797,000 total AF
On-farm irrigation efficiency	72% (item 4/item 2)
District irrigation efficiency	66% (item 4/item 1)

Source: IID Water Reports, 1977-1980.

It is apparent that the District and farmers have increased efficiency and conserved water to such an extent that, as a minimum, the District will conserve at least 100,000 AF annually. The District has attained a high degree of conveyance efficiency - in excess of 91% over a period of years and in excess of 95% in recent years.

Table 4-10 - Water Conveyance Efficiency
(1977-1980, 1983, and 1984)

Year	Net Received by IID (AF)	Net Delivered by IID (AF)	Conveyance Efficiency
Average (1977-1980)	2,734,000	2,496,500	91
1983	2,286,463	2,180,243	95
1984	2,487,608	2,386,328	96

Source: IID Water Report, 1984.

A. Canal Seepage

Based on studies and analyses done by numerous entities, including: (1) the USBR, (2) CDWR, (3) the IID, and (4) Parsons Water Resources Inc., an assessment was made of the amount of water already being conserved through the District's canal lining program. This data is summarized in Table 4-11 and indicates that an estimated 57,000 AF/year is now being conserved as a result of the IID canal lining program, plus an additional 25,000 AF/year is being conserved in the District's seepage recovery systems, for a total of 82,000 AF/year.

B. Operational Discharge

The amount of water loss created by day-to-day operational events is not precisely known because this water is discharged to and mixes with drain water prior to monitoring. However, a review of the literature, coupled with interviews with the operations staff, indicated that prior to the District's conservation management program and the reservoir's construction, a reasonable estimate of the operational loss was approximately 135,000 AF/year. In recent years, the District has been exercising extreme care to reduce operational discharge. It is now estimated that only 88,000 AF/year is lost in this way (see Chapter 5 for development of these estimates). In other words, there has been a reduction in the operational discharge of approximately 47,000 AF/year (135,000 to 88,000) due largely to the use of reservoirs and stressing conservation in operations. Of the 47,000 AF/year, 2,000 AF/year would probably have occurred because of a slight downtrend in overall water use. Of the 45,000 AF/year remaining, it is estimated that 80%, or 36,000 AF/year, was conserved by IID programs.

Table 4-11 - 1985 Water Delivery System Baseline Water Conserved
(AF/year)

System Component	Water Conserved in Lined Sections	Seepage Recovery	Total Water Conserved - IID Canal Program
All-American Canal			
Imperial Dam to Pilot Knob	-	-	-
Pilot Knob to Drop No. 1	-	-	-
Drop No. 1 to Drop No. 4	-	5,000	5,000
Drop No. 4 to Westside Main	0	3,000	3,000
Subtotal	0	8,000	8,000
Main Canals			
East Highline	-	17,000	17,000
Central Main	-	-	-
Westside Main	-	-	-
Briar/New Briar	1,000	-	1,000
Rositas	-	-	-
Vail	-	-	-
Subtotal	1,000	17,000	18,000
Laterals	56,000	-	56,000
Total	57,000	25,000	82,000

Source: Parsons, 1985.

4.3.2 ON-FARM SYSTEMS

For purposes of this discussion, water not beneficially used on-farm is considered to be part of on-farm water losses. Evapotranspiration (consumptive use) is the quantity of water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces in a specific time period. It constitutes the largest on-farm beneficial water use. As water is transpired by crops, salts contained in the irrigation water remain in the soil solution and must be leached from the soil profile to maintain crop productivity. Leach water, applied to prevent salt accumulation in the crop root zone, is also considered a beneficial use.

Tailwater is defined as surface runoff occurring at the low end of the irrigation run as water is being applied. It constitutes one of the largest on-farm water losses. A portion of the total tailwater occurring during any irrigation is necessary for adequate irrigation at the low end of the field.

Assuming a homogeneous soil, the depth of water penetration is a function of time. Consequently to provide sufficient time for absorption of water into the root zone, some tailwater will occur. However, for purposes of this report, all tailwater is considered an on-farm water loss if not recovered and reused.

The portion of applied water percolating beyond the root zone (deep percolation) is considered an on-farm water loss. If excess leach water occurs, it is also considered an on-farm loss. Other relatively minor on-farm losses would include:

(1) Evaporation from water surfaces such as the head ditch, tanks or basins, storage ponds, or tailwater recovery sumps.

(2) Seepage from on-farm distribution facilities.

(3) Consumptive use of weeds growing along the ditches or field boundaries.

(4) Operational losses caused by failure of on-farm water distribution facilities, irrigator errors, and other unforeseen circumstances.

Unit values of the various parameters constituting the general category of on-farm losses were developed to estimate the relative magnitude of each. The totals for projected future scenarios are discussed later in this report, however, as a baseline for the development of these scenarios, the following estimate of current conditions is presented:

Leach Water (AF/year)	Tailwater (AF/year)	Total (AF/year)
280,000	270,000	550,000

As part of the District's 13-Point Program to conserve water (adopted in mid-1976, Appendix F), charges are assessed when excessive tailwater is determined to exist. This measure is estimated (based on an analysis of tailwater decrease since 1976) to currently reduce tailwater by approximately 20,000 AF/year. This estimate is considered reasonable for the program as it now exists.

4.3.3 DRAINAGE/DISPOSAL SYSTEM

The natural drainage system (New River, Alamo River, and miscellaneous tributaries) and the drainage system constructed by the District collect surface runoff, subsurface flows from the on-farm tile drainage system, operational discharges, and groundwater flow intercepted by the drains. Water collected by the drainage system is subject to two types of losses before it is ultimately discharged to the Salton Sea. The first is evaporation from the water surface of the drainage system. The criterion for estimating the magnitude of this loss is based on unit evaporation rates and estimated surface area of the system. The second type of loss is evapotranspiration of phreatophytes and other native vegetation growing in and along the drainage canals. The criterion for evapotranspiration loss is based on estimates of areas of vegetation and unit evapotranspiration rates. At present, no program is in effect to eliminate these losses.

4.3.4 OTHER LOSSES

Other losses include consumptive use of native vegetation on undeveloped lands within the District, evaporation and consumptive use from urban and industrial areas, feedlots, rural residences, recreational areas, and developed lands within the District's service area left fallow. Criteria for estimating the magnitude of these losses are developed in subsequent subsections of this report.

4.3.5 BASELINE SUMMARY

The only losses identified quantitatively in this chapter are those that will serve as the principal criteria for conserved water. Table 4-12 gives the estimate of the water currently being conserved in the ongoing District program.

Table 4-12 - Summary of Baseline Water Conserved

District Program	Estimated Amount Conserved (AF/year)
Canal lining	57,000
Seepage recovery	25,000
Operational discharge reduction	36,000
Tailwater assessment	20,000
Total	138,000

Source: Parsons, 1985.